The US Army's Center for Strategy and Force Evaluation

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STUDY REPORT
CAA-SR-92-10

ARMY PROGRAM VALUE ADDED ANALYSIS 94-99 (VAA 94-99)

VOLUME I - MAIN REPORT

JUNE 1992

PREPARED BY
FORCE SYSTEMS DIRECTORATE

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CAA

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The Value Added Analysis (VAA) methodology is a decision support system that will assist decisionmakers in evaluating and prioritizing competing alternatives in the Program Objective Memorandum (POM) building process. The Value Added Analysis concept uses a family of models to measure an alternative's explicit (objective) contribution to the program as an incremental or decremental change to the current program base. A hierarchical assessment framework is used to develop an alternative's scores. This assessment framework is used to evaluate changes against the current program base as the consequences of program alternatives are considered. Value Added Analysis results in measuring an alternative's relative value in the context of a larger value system. This relative value is either used directly by decisionmakers or is fed into a mathematical optimization model which simultaneously determines an alternative's cost-benefit and conducts a tradeoff between alternatives.

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REPLY TO
ATTENTION OF
CSCA-FSR (5-5d)

14 AUG 1992

MEMORANDUM FOR

DIRECTOR, PROGRAM ANALYSIS AND EVALUATION (DPAE), OFFICE OF THE CHIEF OF STAFF, U.S. ARMY, WASHINGTON, DC 20310-0200
DEPUTY CHIEF OF STAFF FOR OPERATIONS AND PLANS (DCSOPS), WASHINGTON, DC 20310-0410

SUBJECT: Army Program Value Added Analysis 94-99 (VAA 94-99) Study

1. Reference memorandum, Office of the Chief of Staff, U.S. Army, subject: Army Program Value Added Analysis 94-99 (VAA 94-99) Study.

2. Referenced memorandum requested that the U.S. Army Concepts Analysis Agency (CAA) implement the methodology developed in the Army Program Value Added Analysis - Phase I Study. This methodology uses a hierarchical assessment framework for determining return on investment.

3. This report documents the results of our analysis. The principal findings of the study are: (1) VAA Study framework as developed in the VAA Phase I Study was shown to be useful in evaluating Program Objective Memorandum (POM) issues; (2) The use of an experimental design was found to be an effective means to determine system contribution to combat results; (3) The life Cycle Cost Model is a useful tool for computing detailed cost estimates for candidate procurement programs; (4) The development of a mixed integer programing model that considers cost quantity relationships and handles fixed production costs and research, development, test, and evaluation (RDTE) explicitly was shown to be an extremely effective method of cost-benefit analysis; and (5) Additional research is required to find an improved method of effectiveness integration.

4. This Agency expresses appreciation to all commands and agencies which have contributed to this study. Questions and/or inquiries should be directed to the Assistant Director, Force Systems Directorate, U.S. Army Concepts Analysis Agency, 8120 Woodmont Avenue, Bethesda, MD 20814-2797, DSN 295-1546.

E. B. Vandiver III

E. B. VANDIVER III
Director

ARMY PROGRAM VALUE ADDED ANALYSIS 94-99 (VAA 94-99)	STUDY SUMMARY CAA-SR-92-10

THE REASON FOR PERFORMING THE STUDY was to provide the Director for Program Analysis and Evaluation, and the Deputy Chief of Staff for Operations and Plans (DCSOPS) an analytical methodology and capability to support the development of a balanced and effective Army Program.

THE STUDY SPONSORS are the Director for Program Analysis and Evaluation (DPAE), Office of the Chief of Staff, Army, and the Technical Advisor, Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS), Headquarters, Department of the Army (HQDA).

THE STUDY OBJECTIVES were to:

(1) Produce VAA coefficients and feasible acquisition alternatives for major item systems proposed by Headquarters, Department of the Army (HQDA) Long-Range Research, Development, and Acquisition Plan (LRRDAP) and constrained by modernization total obligational authority (TOA). The process must measure and analyze the capability of US Army forces to conduct conventional operations in scenarios consistent with the Illustrative Planning Scenarios of the Defense Planning Guidance, Fiscal Year (FY) 1994-1999.

(2) Identify and develop a Value Added Analysis Capability (VAAC) to include all appropriate hardware, software, and interfaces. The VAAC must tap major authoritative Army data bases such as the Total Army Equipment Distribution Program (TAEDP), Force Accounting System (FAS), and the Army Force Cost System (TAFCS).

(3) Identify or develop models and techniques that support the VAA methodology. The VAAC and related models must be capable of operating in a "quick turnaround" environment, defined as 1 week or less.

(4) Conduct a demonstration of the refined methodology and VAAC prior to the building of the 1994-1999 Program Objective Memorandum (POM).

(5) Continue the refinement and implementation of the VAA methodology for estimating the value of either competing major item systems or management decision packages (MDEPs) to the Total Army Program.

THE SCOPE OF THE STUDY included the research, development, and acquisition (RDA) appropriation for selected major item systems in FY 1994 and FY 2008.

THE MAIN ASSUMPTION of this study is that HQDA needs a relatively quick method for conducting program tradeoffs which has sound analytical underpinnings.

THE BASIC APPROACH of this study was to:

(1) Enhance and expand the analytic approach for program issue tradeoffs developed in Phase I of the VAA study effort.

(2) Develop a VAAC for implementing the methodology to include software modules where appropriate.

(3) Demonstrate the VAAC using issues from the 94-99 POM issue cycle.

THE PRINCIPAL FINDINGS of the study were:

(1) The Value Added Analysis study framework, as developed in the VAA Phase I Study, was shown to be useful in evaluating POM issues.

(2) The use of an experimental design and a response surface methodology was found to be an effective means to determine system contribution to combat results.

(3) The Life Cycle Cost Model (LCCM) is a useful tool for providing action officers with detailed cost estimates for candidate POM programs.

(4) The development of a mixed integer programming formulation that allowed consideration of cost/quantity relationships and handles fixed production costs and research, development, test, and evaluation costs explicitly was shown to be an extremely effective method of cost-benefit analysis.

(5) Additional research is required to find an improved method of effectiveness integration to replace the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Model.

THE STUDY EFFORT was directed by LTC Robert R. Koury, Force Systems Directorate, US Army Concepts Analysis Agency (CAA).

COMMENTS AND QUESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FSR, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

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CHAPTER 1

EXECUTIVE SUMMARY

1-1. PROBLEM. The leadership at Headquarters, Department of the Army (HQDA) needs analysis to support the development of a balanced and effective Army program that is within Department of Defense (DOD) resource guidance.

1-2. STUDY PURPOSE. The purpose of the Army Program Value Added Analysis - Phase II (VAA 94-99) Study was to: (1) enhance the analytical tradeoff methodology developed in Army Program Value Added Analysis 90-97 Phase I; and (2) provide the Director for Program Analysis and Evaluation (DPAE) and the Deputy Chief of Staff for Operations and Plans (DCSOPS) with an analytical capability that would assist in the development of a balanced and effective Army research, development, and acquisition (RDA) program through the use of a comprehensive cost-benefit analysis methodology.

1-3. BACKGROUND

a. Traditionally, Army program development is accomplished during the Planning, Programming, Budgeting, and Execution System (PPBES) Program Objective Memorandum (POM) building process using some form of functional or mission area panels. The processes that evolved do not include adequate means of integrating these functional subprograms into a balanced total Army program. Furthermore, the traditional POM process allowed each panel to use its own methods for prioritization. This lack of standardization prevents the senior leadership from making the most effective tradeoffs across functional areas.

b. Virtually all analysis currently performed in program evaluation focuses on defining individual management decision package (MDEP) issues. When MDEP analysis is conducted, the senior Army leadership lacks the visibility or analysis necessary to help identify the marginal value of resources within, or across, MDEPs.

c. Analysis of the total Army program requires an understanding of how individual MDEPs contribute to the Army mission and strategy so as to determine which MDEPs and resource levels have the greatest return on investment. One approach to this problem is to estimate the "value added" by individual MDEPs, or groups of MDEPs--expressed as program enhancement packages or alternative solutions--to the total Army program as measured by their contribution to Army objectives.

d. The Value Added Analysis concept uses a family of models to measure an issue's explicit (objective) contribution to the program as an incremental or decremental change from the current program base. A survey technique is used to develop an issue's implicit (subjective) contribution to the program through the development of an individual alternative's scores. Saaty's analytical hierarchy technique is used to provide a structure for developing weights for both the explicit and implicit measures of value. Following a detailed analysis of life cycle costs, a cost-benefit analysis is performed using an optimization model to determine the most cost effective acquisition strategy for the candidate systems.

1-4. STUDY OBJECTIVES were to:

a. Produce measures of the worth of the candidate systems (VAA coefficients) and feasible acquisition alternatives for major item systems proposed by the Headquarters, Department of the Army Long-Range Research, Development, and Acquisition Plan (HQDA LRRDAP) and constrained by modernization total obligational authority (TOA). The process must measure and analyze the capability of US Army forces to conduct conventional operations in scenarios consistent with the Illustrative Planning Scenarios of the Defense Planning Guidance, fiscal years (FYs) 94-99.

b. Identify and develop a Value Added Analysis Capability (VAAC) to include all appropriate hardware, software, and interfaces. The VAAC must tap major authoritative Army data bases such as the Total Army Equipment Distribution Program (TAEDP), Force Accounting System (FAS), and The Army Force Cost System (TAFCS).

c. Identify or develop models and techniques that support the VAA Methodology. The VAAC and related models must be capable of operating in a "quick turnaround" environment, defined as 1 week or less.

d. Conduct a demonstration of the refined methodology and VAAC prior to the building of the 1994-1999 POM.

e. Continue the refinement and implementation of the VAA methodology for estimating the value added of either competing major item systems or MDEPs to the total Army program.

1-5. STUDY SCOPE

a. Baseline program is President's Budget, FY 92, and US Program Force (FY 95).

b. The analysis examines the RDA appropriations and other related appropriations as needed to investigate the full programing of selected major item systems.

c. About 50 major item systems based on the following selection criteria: systems without a mission needs statement (MNS) or other requirements document (such as a required operational capability (ROC)) as of 1 October 1991 will not be included, systems with large dollar amounts in current and proposed programs will be included, and finally, inclusion of a system is subject to the ability to execute in terms of data and modeling availability.

d. Scenario Conditions. North Atlantic Treaty Organization (NATO) Central Europe, Post-CFE (Conventional Forces Europe), Defense; Southwest Asia (SWA) Defense with Counterattack; Northeast Asia (NEA) Counteroffensive; consistent with US Army Training and Doctrine Command (TRADOC) scenario(s).

e. Conflict Type. Conventional.

1-6. STUDY LIMITATIONS

a. Since this study is a proof of concept demonstration, the analysis included only the RDA appropriations. Because the modeling and effectiveness data for the noncombat issues are less developed than the combat areas, the study focused principally on combat tradeoff issues.

b. The original list of equipment issues for this study included 23 systems. Limited data available for combat modeling did not permit the inclusion of more than 12 systems in the analysis.

c. RDA appropriations provide only 22 percent of the Army program dollars.

1-7. TIMEFRAME. US Army conventional operations capabilities will be assessed in terms of force packages, major item systems programmed for acquisition, and anticipated threat as of the end of FY 96, FY 01, and FY 08.

1-8. KEY ASSUMPTIONS

a. The President's FY 92 Budget position will be used for both the Program Optimization and Budget Evaluation (PROBE) and Research Development and Acquisition Information System Agency (RDAISA) data bases.

b. The data survey results are assumed to reflect decisionmaker positions and provide a means of modeling the effect of the senior Army leadership on the Army decision making process.

c. There is a 2-year lag from expenditures of procurement dollars to item fielding.

1-9. STUDY METHODOLOGY

a. Introduction. The VAA methodology was developed by the US Army Concepts Analysis Agency (CAA) to provide optimized acquisition strategies across system types, as well as other analysis to support decisionmaking necessary to build the Army budget. The VAA methodology is modular, and each module performs a specific function. Different tools can be used to perform the function of each module depending upon the analytical requirements established by the issue to be examined. Figure 1-1 shows the various modules and their interrelation. A brief description of the modules follows.

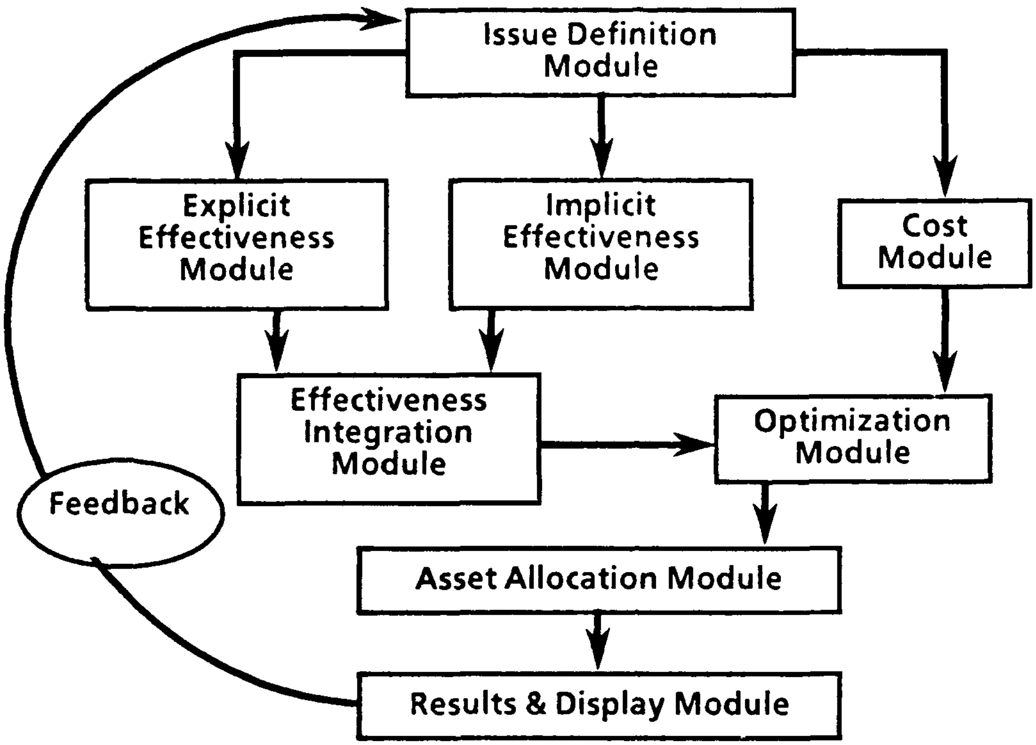


Figure 1-1. Value Added Analysis Modules

b. Issue Definition. The purpose of the Issue Definition Module is to refine the problem and its associated elements to be studied so that the data collection and analysis efforts can be focused on the questions and issues of interest to decisionmakers. Issue definition is a process that continues for the duration of the Value Added Analysis. It establishes the general context of the study in terms of the systems and programs to be analyzed, as well as timeframes and scenarios of interest. The module also encompasses the process of clarifying the specific questions asked by the decisionmakers.

c. Explicit and Implicit Effectiveness. Systems effectiveness is measured in two ways. In the Explicit Effectiveness Module, the systems of interest are portrayed in a combat simulation, and their contribution to force level performance is measured. Not all pertinent criteria that bear on the procurement decision are measurable in this manner. The purpose of the Implicit Effectiveness Module is to quantify these hard-to-measure factors. These factors might include political risk, impact on sustainability, and programmatics, as well as other criteria that cannot be directly measured at present. Evaluations are made by individuals who are experts in these criteria. The criteria are assigned weights of relative importance based on a survey of senior Army decisionmakers. Subject matter experts then evaluate (score) how well a system fares in light of these criteria.

d. Effectiveness Integration. When the programs of interest are finally evaluated, a vector of effectiveness scores for the various criteria is obtained for each system. The purpose of the Effectiveness Integration Module is to reduce this vector of information to a single measure. The Technique for Order Preference by

Similarity to Ideal Solution (TOPSIS) is currently used for this purpose. This method is described in detail by Hwang and Yoon. The single measure obtained for each system can then be used to compare the systems in question with respect to their effectiveness. These measures are used to form the objective function coefficients for the VAA optimization.

e. Cost. Parallel to the determination of the effectiveness of the system in question is the determination of system costs. For the purpose of developing an acquisition strategy, the portion of the life cycle cost of interest is the funds that would be available for research, development, and acquisition (RDA). Data are also collected describing the various components of the RDA costs: fixed costs, variable costs with learning curve effects, and variable costs without learning. These are the costs that are used to build the budgetary constraints for the VAA Optimization Module. After the acquisition strategies are developed, accounting and analysis of total life cycle costs are then conducted.

f. Optimization. Previous mixed integer programming problems have been used at CAA to produce acquisition strategies for various systems such as helicopters or trucks. The need arose to provide optimized acquisition strategies across system types, and to use of nonlinear cost learning curves, which more accurately represent system costs as a function of quantity produced. The Value Added Linear Optimization of Resources (VALOR) Model, a mixed integer linear programming formulation that uses a piecewise linear approximation of the learning curve costs for a more accurate portrayal of budgetary constraints, was developed to meet this need. The objective of the VAA Optimization Module is to maximize the effectiveness of the force subject to constraints on budget, force structure, and production capability.

1-10. ESSENTIAL ELEMENTS OF ANALYSIS (EEA). The essential elements of analysis and basic findings for each are as follows.

a. EEA 1. What is the "value added" of a select number of major item systems to be considered in the 1994-1999 Program Objective Memorandum (POM)?

(1) Initially a list of 119 systems was reviewed for the VAA Phase II effort. This list was revised using a set of criteria which included the ability to model the system, the existence of a system requirements document, and the determination that the system represented a major acquisition in terms of the total dollars associated with the system's program. The first cut of the original 119, based on the previously mentioned criteria, resulted in a list of 50 major item systems. Each of the systems on this "first cut" list were modeled in the Corps Battle Analyzer (CORBAN). As decisions were made by the Army leadership, several systems were dropped from consideration. The final list consisted of 41 systems.

(2) The "value added" of each of the systems by year (FY 96, FY 01, and FY 08) given as a 1 to N list developed from the effectiveness integration module was produced. This list is provided in Chapter 9.

b. EEA 2. What kind of characteristics should the VAAC have in order to implement the VAA methodology?

(1) As defined in the VAA Phase I Study, the VAAC was to be a set of models and tools residing on the METAPHOR computer architecture. The advantages of this arrangement as originally developed was it would allow the action officer in the Pentagon to use the data base engine of METAPHOR to define and shape the issues to be studied. The action officer would then use the ability of METAPHOR to move in and out of the personal computer (PC) environment in order to run the VAA models and tools for conducting a value added analysis. CAA, the Program Analysis and Evaluation Directorate (PAED), and Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) Information Management Office (IMO) were able to obtain connectivity and many of the tools and unique VAA data bases were placed in the METAPHOR environment. However, the ability to move in and out of the METAPHOR environment into the PC environment was found to be somewhat limited. This limitation coupled with time and resource constraints associated with having action officer attempt to do these types of analyses prohibited the implementation of the proposed VAAC design during the study period.

(2) It was determined that the action officers in the Pentagon were unable to find the time to learn either the METAPHOR computer software or the VAA tools. This constraint indicated that the VAAC would have to be designed to allow the action officers access to the input data, issue definition narrative data, and then to the results of the value added analysis. However, the value added analysis would need to be conducted by an analytical organization outside of the HQDA Army Staff (ARSTAF) or by a special study group. The need to have a separate study group and visibility/access for the action officers creates the requirement for the VAAC to be able to move easily from a data base environment into a decentralized computational environment and back again. The ability to pull data from the Army corporate data bases, format the data, and then move that data into the VAA tools and models must be well developed. The connectivity of data and tools must be enhanced over the manner in which this type of function was handled in VAA Phase II, which was the hand-carrying of data on disks from one machine to another. The study group conducting the analysis should be able to move from the IBM RISC 6000 computer to the Macintosh computer and back to the data bases in manner which is transparent to the analyst. Likewise, the action officer must be able to query the results of the study group work, the assumptions for the work, and the input data for the particular work.

c. EEA 3. What kinds of tools, techniques, and models are needed to support the VAA methodology?

(1) The VAA Phase I effort investigated the idea of using spreadsheet costing tools, a simplified optimization, and the use of CORBAN for the combat modeling. Much of the work that was completed during Phase I was hand generated with little experience as to how data or processes might be connected. The major thrust of the VAA Phase II effort was to develop a more complete combat modeling capability, expand the optimization tool, implement the changes to TOPSIS recommended by the Operations Research Systems Analysis (ORSA) Center at the US Military Academy (USMA), and take the cost analysis concepts and grow them into a full set of tools. The survey technique developed during VAA Phase I and the use of the analytical hierarchy process remained relatively unchanged. The only changes associated with these last two techniques was the development of a different hierarchy. This was not

a matter of change in technique as much as it was defining the context for the VAA Phase II effort. Essentially, the survey approach was the same in both phases.

(2) The first model improvement needed to support the VAA methodology included a combat model which was both easier to set up and faster in its run time than the stochastic CORBAN used in the Phase I study. The team looked at other models such as Analysis of Force Potential (AFP), Eagle, and Vector-In-Commander (VIC) as possible solutions. It was decided that AFP was at too aggregated a level, that Eagle was not yet developed enough to use, and that VIC was at too high a level of resolution. All of these models also had the same limitations as CORBAN in that they all have extensive setup requirements. This review of the combat models had the net effect of validating the need for CORBAN. However, the team determined that a full factorial design using stochastic CORBAN was not possible. Therefore, the team worked with TRADOC to obtain a deterministic version of CORBAN in an effort to speed up the run time. This change proved to be extremely important because in allowed the team to perform excursions relatively rapidly. However, in order to develop values for all 41 systems, a very large experimental design was required. Even a deterministic CORBAN was not fast enough to accomplish all the runs required. The requirement to perform many excursions for a large range of weapon system mixes led to the use of a response surface methodology (RSM). The VAA Phase II experience in using RSM was very favorable. The RSM technique allowed the team to accomplish the development of values for all of the systems. RSM also had a side benefit in allowing the team to predict the explicit measure of effectiveness (MOE) values one would obtain by playing the weapon mix coming out of the optimization.

(3) A more fully developed optimization formulation was another technique/model needed to fully implement the VAA methodology. In VAA Phase I, a relatively simple formulation was used for the linear program in order to demonstrate the feasibility of the methodology. It was evident that any follow-on effort had a need for dynamic cost-quantity modeling to accommodate the concept of system learning curves in order to provide a more accurate cost within the optimization. Phase I also identified the requirement to link certain systems together if they are dependent upon one another, for example Advanced Field Artillery System (AFAS) and future armored resupply vehicle - artillery (FARV-A), where FARV-A is not procured unless AFAS is being procured. Finally, the capacity to continue to fully incorporate both force structure and production data was maintained, along with institution of better quality control on the data.

(4) VAA Phase I validated the concept of using a linear combination technique for integrating the effectiveness values. The TOPSIS technique used in Phase I was reviewed by the ORSA Center at USMA. Their suggestions for improvement were implemented in the Phase II Study.

(5) The cost analysis tools developed as part of this VAA Phase II effort by the sponsors have proven to to be very useful. The Life Cycle Cost Model (LCCM) has been expanded and refined to include the ability to conduct "what ifs" on quantities and average unit costs. The tool has been transferred to HQDA PAED and is currently in use by PAED analysts. Further refinement to include the development of generic LCCMs by mission area would be useful in conducting analysis on developmental systems which currently do not have a baseline cost estimate (BCE).

d. EEA 4. What explicit effectiveness models are most appropriate for a Value Added Analysis Study (Value Added Analysis 1994-1999)?

(1) In VAA Phase I, the issue of using a highly aggregated combat model was addressed. The conclusion was that an aggregated model could provide useful insights for answering macro level program tradeoff questions. However, it was also noted that decisionmakers require sufficient detail to understand the reasons for combat outcomes to assist them in specific program decisions. This point was reinforced in work completed as part of VAA Phase II. Almost universally, decisionmakers wanted to know the reasons behind the combat results. The use of RSM compounded the problem by not considering the effects of interaction and only looking at the first order effects. This tradeoff between detail and the ability to look at a large number of systems will continue to be an issue.

(2) This particular EEA was aimed at a larger issue than just the research, development, and acquisition (RDA) appropriation modeling and the combat modeling associated with study weapon system tradeoffs. At the outset, VAA Phase II was starting to look at other appropriations such as Operation and Maintenance Army (OMA), Military Construction Army (MCA), and perhaps Military Personnel Army (MPA). Although these appropriations were considered, especially in the LCCM costing, true tradeoffs were not conducted. The team did explore some preliminary tradeoffs in the area of OMA to RDA and MPA to RDA. This preliminary work suggests that additional explicit effectiveness models are required, such as operational tempo (OPTEMPO) models, training models, and the inclusion of campaign models. This is an area which requires additional research as part of a follow-on study.

e. EEA 5. What refinements are needed to improve the VAA methodology? Answers to the previous EEA suggest some areas for refinements already. The work completed in the VAA Phase II effort has shown that the methodology works and can provide useful and timely support to decisionmakers. Additional work is needed to expand the use of the methodology into a broader range of issues. These include a variety of combat systems (e.g., logistics and command and control (C^2)) and other appropriations (e.g., OMA and MCA).

1-11. OTHER KEY FINDINGS. The observations and findings contained in this paragraph are not keyed to the original questions proposed in the study directive, but are insights obtained as a result of the work completed in this study.

a. Input data intensity, accuracy, and timeliness continue to be of crucial importance in making the value added process operational.

b. The need to have the survey process standardized was confirmed in this study.

c. Issue definition is clearly an iterative process and should not be thought of as having a beginning or ending, *per se*.

d. Future experimental designs should try to incorporate the need to investigate second order effects (i.e., synergism and weapon system interactions).

e. Production data as depicted in the HQDA procurement (P-21) forms, which are used to provide procurement information to Congress, are not sufficient or timely enough to conduct Value Added Analysis on an institutionalized basis. The production data required for Value Added Analysis (as well as for other acquisition analyses conducted for HQDA) should be made readily available and current in support of budgetary decisionmaking.

f. Standardized cost codes and views as implemented in the VAA Phase II Value Added Analysis Study should be used throughout the Army. The Life Cycle Cost Model should be made available to Program Executive Offices (PEOs)/ Program Managers (PMs) and help form the basis for standardization.

g. Major item system data as defined in the Army Resource Integration and Management (ARIM) Study should be institutionalized and used throughout the procurement process to assist in standardization of costs and system definition.

CHAPTER 2

INTRODUCTION

2-1. OVERVIEW

a. The primary purpose of this chapter is to provide a discussion of the background which influenced the conduct of the Phase II VAA Study. Additionally, this chapter provides a discussion of the limitations and assumptions associated with the Phase II work and a brief overview of the methodological refinements developed as part of Phase II.

b. The purpose of the Phase II Study was to implement the VAA methodology as created and defined in the Phase I work. The study focused on refining the VAA methodology and actually assisting the ARSTAF in allocating resources for modernization programs. The latter was accomplished by using the VAA methodology as part of the LRRDAP review process. The VAA Phase II study directive identified five objectives to be accomplished as part of the study. In meeting these objectives, the study produced VAA system coefficients and a series of feasible acquisition alternatives. The study identified, and, to a limited degree, developed a Value Added Analysis Capability which included all appropriate hardware, software, and interfaces. Finally, the study team identified and developed models and techniques that supported the VAA methodology. Chapter 2 is structured as follows:

- Problem Background
- A Review of the VAA Phase I Findings
- VAA Phase II as an Outgrowth of VAA Phase I
- Methodology Overview
- Methodological Refinements
- Summary

2-2. PROBLEM BACKGROUND

a. The growing federal budget deficit and the breakout of peace in Europe have put great pressure on all of the armed services to reevaluate and restructure their budget and programs. This pressure is especially great on the Army because of the changing perception of the threat in Western Europe. There is more need now for cost-benefit analysis than ever before. This analysis must be conducted in support of developing a balanced and effective Army program within Department of Defense resource guidance. Traditionally, the Army has used functional area panels to build its POM. The processes that have evolved do not include adequate means of integrating and balancing the functional programs into the total Army program. The Value Added Analysis has been conceived as a means of assisting in accomplishing this integration and balancing.

b. The environment in which Value Added Analysis must be conducted is characterized by minimal time for analysis, ever-changing assumptions, often incomplete data, and increasing emphasis on verifiable results. Traditional staff

processes and supporting operations research studies often do not meet this challenge. This failure occurs because traditional approaches require a long time and highly trained personnel to produce high quality, fully integrated, and very detailed analysis.

c. The requirement for a Value Added Analysis methodology was conceived by the Director, Program Analysis and Evaluation, as a means of conducting program tradeoff analyses. In early 1989, DPAE, asked the Technical Advisor, DCSOPS, to jointly sponsor a study to be conducted by CAA to develop this methodology. The subsequent study was called Army Program Value Added Analysis 90-97 (VAA 90-97) and was completed in August of 1991. The primary purpose of the VAA Phase I Study was to develop and demonstrate a methodology for conducting marginal cost-benefit analyses.

2-3. A REVIEW OF THE VAA PHASE I FINDINGS

a. Background. The VAA Phase I Study was designed as a proof of concept to include the building of a prototype decision support system. Because the work was developmental, the study team limited the scope to weapon system tradeoffs and did not attempt to address force structure, personnel, infrastructure, or other issues. The methodology was, however, designed to be generic and used across all the functional areas of the Army program.

b. Primary Observations and Findings. The primary finding of the VAA Phase I Study was the definition of a flexible and rational methodology to support the POM process and Army program development. However, the study team was not able to completely automate the decision support system. The study team found that a linear combination of value components creating a single measure of an issue's marginal value was effective in ranking alternatives and conducting tradeoff analyses. However, the techniques available for doing this combination have several analytical weaknesses including scale compression, inadequate treatment of equivalence classes, and sensitivity to probabilistic inputs. The methodology developed during VAA Phase I was successful in capturing the subjective elements used by decisionmakers in conducting tradeoffs between alternatives through the use of judgment weights. The VAA Phase I Study also provided some important insights into the use of aggregated effectiveness models, new costing approaches, and optimization techniques which were built upon in this Phase II Study. The following is an abbreviated list and discussion of the EEAs, observations, and findings:

(1) Two generalized categories of measures (explicit and implicit effectiveness) were discovered to be important in judging relative value.

(2) Viewing system effectiveness as an integrated piece of force effectiveness, instead of measuring pure weapon system performance, yields a more rational view of weapon system contribution across systems and mission areas.

(3) Implicit effectiveness factors (secondary impact analysis modifiers (SIAM) factors) beyond explicit (pure combat) effectiveness are a significant component of the Headquarters, Department of the Army (HQDA) decision process, and a management survey can yield important inputs into this process.

(4) No one single measure of combat effectiveness is adequate to measure the contribution of weapon systems. Establishing a hierarchy of MOE was found to be an effective way to use results from different models.

(5) The systematic specification of costs and benefits within a consistent framework understood by both analyst and decisionmaker is an extremely positive feature of the methodology.

c. **Other Observations and Findings.** The observations and findings contained in this paragraph are not necessarily keyed to the original questions proposed in the study directive but are insights obtained as a result of the work completed in the VAA Phase I Study.

(1) The Value Added methodology is data intensive. Accuracy and timeliness of input data, especially production data, is of crucial importance in making the value added process operational.

(2) The initial goal of value added was to be quick turnaround for all components. What was found was that an extensive front-end process (especially combat modeling and costing) was required which consumed large amounts of time.

(3) The Value Added methodology will "buy" the most cost effective systems subject to constraints.

(4) The study developed a modular "living" methodology with extreme flexibility that can be used with a variety of techniques and models.

(5) Issue clarification is difficult, and it appears that senior decisionmakers have difficulty focusing issues.

(6) The technique used to survey the Army leadership allows decision making attitudes and behaviors to be accurately modeled.

2-4. VAA PHASE II AS AN OUTGROWTH OF VAA PHASE I

a. Upon completion of the VAA Phase I Study, an evaluation of the results was conducted to determine the direction of VAA Phase II. The Value Added Analysis study effort was originally planned as having two parts. The study team and sponsors intended to have Phase I develop the methodology and Phase II implement that methodology within HQDA at both PAED and ODCSOPS. The view was that a decision support system would be implemented on the METAPHOR computer which would allow action officers at HQDA to frame and conduct their own Value Added Analyses. As indicated in the previous paragraph, it became evident to the study team and the sponsors that a quick turnaround, in-house analysis capability would not be possible as originally envisioned. The initial view of implementation had the entire data collection effort and combat modeling being completed at HQDA. The idea that an analytical agency would be needed to conduct the analysis was not part of the plan. However, as the study team gained experience and a better understanding of the components of the methodology was developed, it became evident that an extensive upfront analysis would be required. This finding was important in shaping the VAA Phase II Study because it now pointed to the need for the continuing involvement of an analytical agency in the VAA study process.

b. The VAA Phase I finding which indicated the need for extensive upfront analysis by an analytical agency helped shape a new view of the division of labor or study effort between a yet unidentified analytical agency and the action officers at HQDA. This finding also required the VAA Phase II implementation effort to change

its focus slightly. The idea of implementing a complete handoff of all analysis to the action officer changed to one in which the combat modeling, data collection, and optimization formulation would be completed at a location other than HQDA and periodically refreshed. HQDA would be involved in helping shape the upfront analysis and would use the data bases created as a result of the analysis to conduct their inquiries and analysis. Keeping this change in mind, the study team started to develop its plan for implementation.

c. The following scope, limitations, and assumptions were used in conducting the VAA Phase II Study:

(1) The baseline program which was used included the President's Budget FY 91 and US Program Force as of FY 95.

(2) The analysis focused primarily on the research, development, and acquisition appropriations and only looked at other appropriations as needed in order to relate back to the RDA accounts.

(3) The analysis examined 41 major item systems.

(4) The analysis considered US Army conventional operations in terms of force packages, major item systems programmed for acquisition, and anticipated threat as of the end of FY 96, FY 01, and FY 08.

(5) Three scenarios were considered in developing the combat modeling and analytical hierarchy to include a NATO Central Europe - post-CFE defense, a SWA defense with a counterattack, and an NEA attack.

(6) The VAAC will initially be installed at CAA, but would be eventually installed at PA&E and ODCSOPS.

d. Although the focus on where the analysis would be conducted changed, the basic methodology did not. It was determined that the overall methodology as developed in VAA Phase I was still viable, and that the methodology only required certain refinements in order to implement it for the conduct of actual analyses.

2-5. METHODOLOGY OVERVIEW

a. The first objective of this study, as outlined in the study directive, was to implement the VAA methodology as created and defined in the Phase I work. This study focused on refining the VAA methodology and actually assisting the ARSTAF in allocating resources for modernization programs. The VAA methodology has been developed to provide a road map for conducting these analyses. The methodology provides a generic approach for cost-benefit analysis. An important feature of this methodology is that it is flexible and may be used in both a standardized or *ad hoc* approach. The VAA standardized approach would use the complete methodology as described in this chapter, to include all of the current techniques developed. The *ad hoc* approach uses only those modules and techniques pertinent to the issue being investigated. This flexibility is achieved by using a modular methodological framework. Figure 2-1 depicts the complete "standardized" VAA methodology with its eight modules.

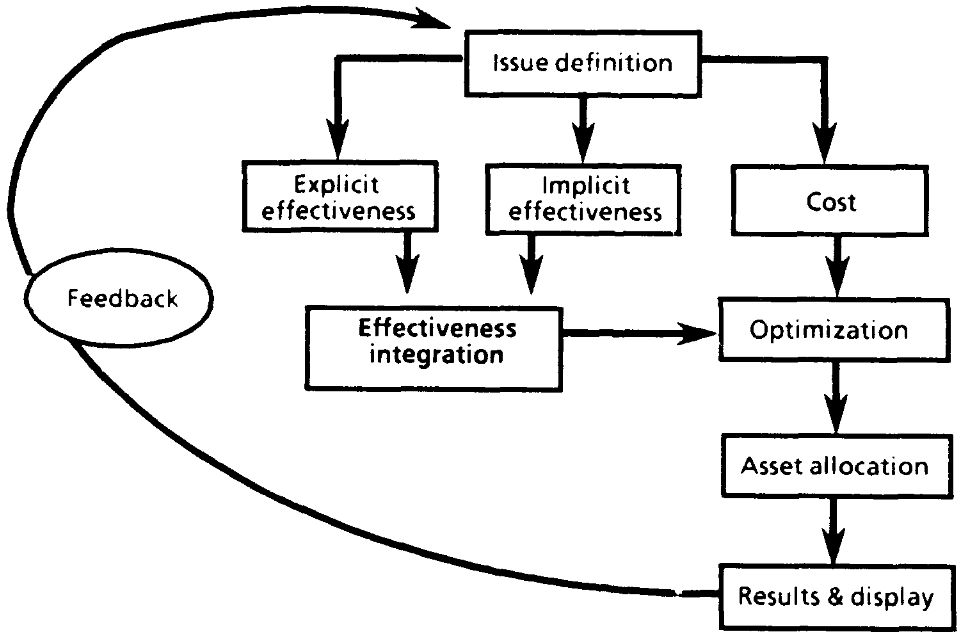


Figure 2-1. Value Added Analysis Methodology Overview

b. Although the VAA methodology is designed to be generic and to be used with any of the appropriations (e.g., OMA, MCA, RDA, etc.), the Phase II study effort concentrated primarily on the RDA accounts. The VAA methodology for the RDA appropriation consists of the following steps:

(1) **Step 1 - Issue Definition**. Identify and define issues. Select analytical tools and data required to address them.

(2) **Step 2 - Explicit Effectiveness**. Using a combat simulation model, determine the relative contribution of selected systems to force-level combat effectiveness.

(3) **Step 3 - Implicit Effectiveness.** Based upon survey input from subject matter experts, assign scores to the selected systems, indicating their rating with respect to the implicit effectiveness factors.

(4) **Step 4 - Effectiveness Integration.** Based upon a survey of senior Army leaders, derive weights for factors that influence the decisionmaking process. The senior Army leader survey produces weights that reflect the relative importance of different combat scenarios (for selected years) and explicit and implicit effectiveness factors in the decisionmaking process. A mathematical prioritization tool combines the results of the combat model and the subject matter expert and senior Army leadership surveys and produces a list of systems rank-ordered according to their relative effectiveness, as well as a numerical measure of that effectiveness.

(5) **Step 5 - Costing**. Life cycle costs which include materiel, personnel, and system-specific facility expenses are produced for the selected systems. Several cost looks can be produced depending on user need.

(6) **Step 6 - Optimization**. System effectiveness and costs are evaluated in a mathematical optimization model that develops an affordable, feasible program alternative--i.e., what should be bought, how many, and when--while accounting for budget and production constraints, force structure requirements, production capabilities, and learning curve effects.

(7) **Step 7 - Resource Allocation**. System distribution can be estimated across the Army in accordance with Army distribution priorities. This module was not directly exercised in VAA Phase II.

(8) **Step 8 - Results and Displays**. Results are displayed in a wide variety of formats to meet the needs of the sponsor.

c. As currently implemented, five of the eight VAA modules have been fully used in conducting the VAA Phase II analysis and follow-on quick reaction analyses (QRAs). Of the remaining three modules, issue clarification and results/display have been used in these studies, but no specific tools or models have been developed for their implementation. Only the resource allocation module has never been used. All of the methodological refinements have concentrated on those five modules which actually implement the VAA methodology for the RDA appropriations. The VAA Phase II study directive also listed the implementation of the VAA methodology on the METAPHOR computer systems at HQDA as a requirement. The study team has had limited success in accomplishing this task.

2-6. METHODOLOGICAL REFINEMENTS

a. As an outgrowth of the findings from the VAA Phase I Study, several methodological refinements were suggested. Three general areas requiring refinement included combat analysis, development of weights for the coefficients, and optimization. Although improvements to the costing methodology did occur, the basic structure and approach to the cost analysis did not change. Each of the three areas is discussed in more detail in the following paragraphs.

b. The refinements to the combat analysis came in two areas. These areas included refinements to the combat simulation, CORBAN, in terms of the systems considered, and the development of a method to handle large mixes of systems without conducting full-scale simulations. First, the quality and quantity of the combat simulations were greatly improved. The original work completed in VAA Phase I was very limited in scope. Only nine systems were simulated in the first phase in only one scenario. VAA Phase II increased both the number of systems (to 41), and the scenarios included were increased to 3. The increase in the number of systems represented not only a numerical difference, but also a difference in the variety of mission areas to be considered. This increase was intended to represent the full spectrum of issues the methodology would be required to handle. The other improvement involved the development of a response surface methodology to handle the increased number of systems for consideration. It became obvious that the larger number of potential mixes of systems could not be individually simulated in separate runs as was done in the VAA Phase I work. The overhead and time required to do so was too great to be feasible within given time constraints. An experimental design was introduced which allowed the building of a response surface that could be used to estimate the combat contribution of each system being considered and predict the combat outcome that would be obtained if a particular mix was played. The net effect of both of these refinements was to make the VAA approach more useful in dealing with real-world problems and issues.

c. The second major area of refinement dealt with the building of the weights for the effectiveness criteria. The basic survey approach remained unchanged from the procedure in the Phase I Study. The most significant refinement to this section of the methodology came in the manner in which TOPSIS was used to build the weights. Saaty's analytical hierarchy process (AHP) was used to develop the framework for combining the measures of effectiveness into a single value. However, at the lowest level of the hierarchy, TOPSIS was used to combine the criteria in order to apply the higher level (higher in the analytical hierarchy) weights. This area has been, and remains, one of the areas requiring further research and refinement.

d. The refinement of the optimization was probably the most significant area of methodological improvement. In VAA Phase I, a very simplified linear programming formulation was used in order to prove the concept of VAA. The VAA Phase I findings clearly indicated the need to consider cost/quantity relationships, production line capabilities, and greater detail in regard to force structure constraints. The VALOR formulation for the Phase II Study incorporated a piecewise linear approximation of costs with respect to quantities. The ability to manipulate these relationships within the optimization algorithm allowed the model to reflect the effects of economies of scale on the procurement recommendations, ensuring a more realistic and executable program. The ability to handle production line criteria was not

enhanced greatly during the VAA Phase II Study. However, the model did explicitly handle production line consideration to include production years and campaigns. The ability to link systems together because of force structure and operational considerations was important to ensure rational and executable programs. The recommended strategies developed from this formulation obtained a high level acceptance among the decisionmakers because of the constraints listed above.

2-7. SUMMARY. The VAA Phase I Study provided a solid foundation for the conduct of weapon systems tradeoffs. The Phase II Study was able to build upon that foundation. The improvement was especially true in the areas of RSM for predicting combat results, the extension of the Life Cycle Cost Model to include the 41 systems of Phase II, and the formulation of VALOR to incorporate learning curve costing and system linkages.

CHAPTER 3

ISSUE DEFINITION

3-1. INTRODUCTION

a. The purpose of this chapter is twofold. First, the Issue Definition module is explained and its evolution during the VAA Phase II effort is discussed. Second, the factors that established the broad context of the VAA Phase II Study and the rationale behind them are discussed. These factors include timeframes, scenarios, list of major item systems to be analyzed, combat MOE to be used, and implicit factors to be utilized.

b. During the conduct of the VAA Phase II Study, it was found that previous thoughts and assumptions regarding how issues would be provided by the study sponsors, particularly those that were described in the VAA Phase I Study Report, would have to be modified. The primary assumption was that issues would be fairly well defined and that some set procedure could be used to structure them into the form needed to perform value added analysis. This assumption turned out to be false. Typically, issues were stated in an ambiguous manner, and a great deal of negotiation and iteration were needed to achieve the necessary form. It was also found that issue definition was an ongoing process rather than one that would be completed early in the study. The reason for this effect was that, as the study progressed, the sponsors and the study team became more comfortable with using the VAAC. Often, when one question was answered, others were generated, and a feedback loop was established.

c. Issue definition can be categorized into two distinct, but related, pieces. The first revolves around establishing the broad context for the study. This context is developed by defining the factors listed in paragraph 3-1a above and is accomplished at the beginning of the study. This process is described in detail in this chapter. The second piece involves framing in specific terms the questions regarding individual systems and groups of systems so that recommendations can be made about tradeoffs and mixes of these systems to be procured. These questions were answered in a series of QRAs and are summarized in Chapter 9.

d. The remainder of Chapter 3 is structured as follows:

- Timeframes
- Scenarios
- Major Item Systems List
- Explicit MOE
- Implicit Factors
- Summary

3-2. TIMEFRAMES

a. As mentioned previously, the VAA Phase II Study was to analyze the procurement of equipment in support of the construction of the FY 94 - FY 99 POM. Thus, these years were of primary importance during the study. Also of importance were the years of the Extended Planning Period (EPP) which are FY 00 - FY 08. Often, data describing the developmental systems that were candidates for procurement during the EPP, including cost, effectiveness, and production data, were not as reliable as that describing systems to be procured in the POM years. Nevertheless, extreme care was exercised to ensure the best data available was used.

b. Different systems perform better or worse depending on the level of modernization of the enemy and on their interaction with different friendly systems. These factors are a function of the timeframe, so the systems must be evaluated over the range of years under consideration. Unfortunately, the available resources were inadequate to perform the number of combat simulation runs that would be needed to evaluate every system in every year that it could be in the force. As such, the decision was made to choose a representative sample of years and simulate only those. These years were FY 96 which represented the near-term, FY 01 which represented the mid-term, and FY 08, which represented the far-term. Note that the assumption is made that equipment procured will not be available for fielding for 2 years. Thus, the mid-term timeframe represents the first year that all equipment procured in the POM years is available in the force. Note also that threat data was not available for the FY 08 timeframe. The latest approved threat data was for FY 04. Consequently, an FY 04 threat was used for the far-term scenarios.

3-3. SCENARIOS

a. The original plan for VAA Phase II called for the following three scenarios to be used: Conventional Forces Europe, Southwest Asia, and Northeast Asia. Each of these scenarios was to be portrayed in each of the three timeframes.

b. Subsequent to the decision regarding the scenarios, the threat posed by the Soviet Union in Europe was greatly reduced, resulting in the lessening of the importance of the CFE scenario. The decision was made, however, to continue to include the CFE scenario in the analysis since the scenario represented a situation in which US forces faced a high-tech enemy. The use of this scenario was consistent with the concept of capability-based requirements.

c. Whereas data existed to use as a starting point for building the SWA and CFE scenarios for the combat simulation model, none existed for the NEA scenario. As a result, data had to be assembled from scratch, greatly increasing the time required to perform the simulation of this scenario. It became evident that finishing these runs in time for use in the analysis was impossible. As a result, this part of the effort was abandoned so that more resources could be applied to the other scenarios.

d. The result of the above was that combat results were available for CFE and SWA only. These results were later referred to as the Stressful Scenario and the Contingency Scenario, respectively.

3-4. MAJOR ITEM SYSTEMS LIST. The decision regarding which systems should be included in the VAA Phase II Study was made jointly by the sponsors and the study team. The criteria used to decide whether a system should be included was the team's ability to model the system, the existence of a system requirements document, and the determination that the system represented a major acquisition in terms of the total dollars associated with the system's program. The "first cut" of the original 119, based on the previously mentioned criteria, resulted in a list of 50 major item systems. Each of the systems on this "first cut" list were modeled in CORBAN. As the team gained experience with particular systems and as decisions were made by the Army leadership, several systems were dropped from consideration. The final list consisted of 41 systems. A list of the systems included in the VAA Phase II Study is provided in Chapter 4, together with the timeframes in which they are available for fielding.

3-5. EXPLICIT MOE. In the Phase I effort, three explicit, or combat, MOE were used. These were Blue force surviving (BFS), Red force movement (RFM), and correlation of forces and means (COFM). In addition, loss exchange ratio (LER) was calculated but was not used. Subsequent analysis revealed that all of these MOE except BFS were highly correlated, indicating that they were measurements of the same criteria. As the result of this analysis, the decision was made to reduce the number of explicit MOE to two, one measuring the lethality of the force, and the other measuring the survivability of the force. Force exchange ratio (FER) and BFS were chosen to fill these respective roles. This reduction in the number of explicit MOE had the additional benefit of reducing the number of pairwise comparisons needed in the Senior Leader Survey. Chapter 5 describes this survey and gives its results.

3-6. IMPLICIT FACTORS. As was the case with the explicit MOE, the number of implicit factors used was reduced. Where Phase I utilized 11 implicit factors, 6 were used in Phase II. The following are the implicit factors that were used. These factors are defined in Chapter 5, and they represent an attempt to eliminate duplication and factors that were not considered important in Phase I.

- Political risk,
- Programmatics,
- Asset versatility and deployability,
- Operation and technical risk,
- Criticality of need with respect to existing capabilities, and
- Impact on sustainability with respect to combat.

3-7. SUMMARY. The process of setting the modeling and context of the Value Added Analysis is undoubtedly the most important step in the VAA methodology. The results have a long-term effect on the capability to provide timely and useful analysis in the POM building effort. As such, extreme care must be taken to thoroughly think through all the ramifications of the decisions made in this module.

CHAPTER 4

EXPLICIT MEASURES OF VALUE

4-1. COMBAT EFFECTIVENESS

a. Introduction. The purpose of this chapter is to explain the development of the combat context for Army Program Value Added Analysis 94-99 (VAA 94-99), to describe the models and tools used in the development of the measures of effectiveness, and to present the VAA Phase II scenarios and the results of the simulation runs.

b. Development of Combat Context

(1) Guidance. Unlike VAA Phase I, where the TRADOC-approved scenarios were used, the scenarios in the Total Army Analysis, 92-99 (TAA-99) were used in VAA Phase II; these scenarios adhere to Defense Guidance. Since the TAA-99 scenarios were used for theater-level simulations in the TAA-99 Study, the locations and strengths of units required to implement the corps-level scenarios were readily available. Other modifications were dictated by the unique requirements of the VAA Phase II cost-benefit analysis.

(2) Requirements for VAA Phase II

(a) The following are the scenario requirements for VAA Phase II. First, since VAA is an incremental analysis, the base case items did not require combat effectiveness measures. Only the VAA candidate systems which are portrayed in the excursions need to be measured with respect to their contribution to combat effectiveness. Next, situations must be varied by the terrain, postures, missions, and threats. Third, the scenarios must be based upon approved Army doctrine and related to Total Army Analysis (TAA). Finally, all major weapon system groups must be exercised, to include system substitutions and comparisons and to stress systems, not forces.

(b) Certain modifications to scenarios and indeed to doctrine are required to enable a cost-benefit type analysis to be performed. For example, doctrine may call for a flanking maneuver which bypasses the enemy. However, if this tactic is employed, some weapon systems may not become engaged, and these systems' effectiveness cannot be measured. Therefore, although doctrine may call for a bypassing maneuver, an attack into the enemy may be executed to ensure that the systems of interest are well exercised. Note that the values of the MOE can be altered by changing the intensity of combat the system endures. Care must be taken to ensure that all tactics employed in the combat simulation are reasonable.

(c) The following are the modifications to the TAA-99 scenarios that were incorporated when building VAA Phase II scenarios. First, only US assets were considered, since VAA is concerned only with US Army programs, and assets were limited due to the current combat model size constraints. Next, the focus of combat effectiveness measures was on modeling one US corps. This level of resolution was found to be most appropriate, since systems could be portrayed in adequate detail to ascertain their individual contributions to the outcome of battle, which would not have been the case using existing theater-level models; but it did include sufficient command and control and logistics aspects that would not have been available if the division level of resolution was used. AirLand Operations doctrine was used whenever possible. Finally, the Army of Excellence force structure was used.

(d) The following scenarios were planned to be used for the simulations to cover the programming period: SWA, CFE, and NEA. The period of interest in VAA Phase II is FY 94-99, the POM period, and FY 00-08, the EPP. A lag time of 2 years between systems procurement and fielding was assumed. For example, systems procured in FY 94 would be available to fight an enemy in FY 96. The EPP actually extends to FY 08, requiring a simulated battle in FY 10. However, threat data was not available for that timeframe, so the available FY 04 data was used. For each scenario, simulated battles were conducted representing FY 96, the beginning of the POM period; FY 01, the end of the POM period; and FY 08, the end of the EPP. A complete description of the scenarios is given in Volume II, Appendix F, published separately.

c. Analytical Models and Tools

(1) Corps Battle Analyzer (CORBAN). The version of CORBAN, as used in VAA Phase II, is a deterministic force-on-force simulation of corps-level battles at battalion-level resolution. Figure 4-1 lists the input and output parameters of the model. For a more complete description of CORBAN, see the CORBAN User's Guide.

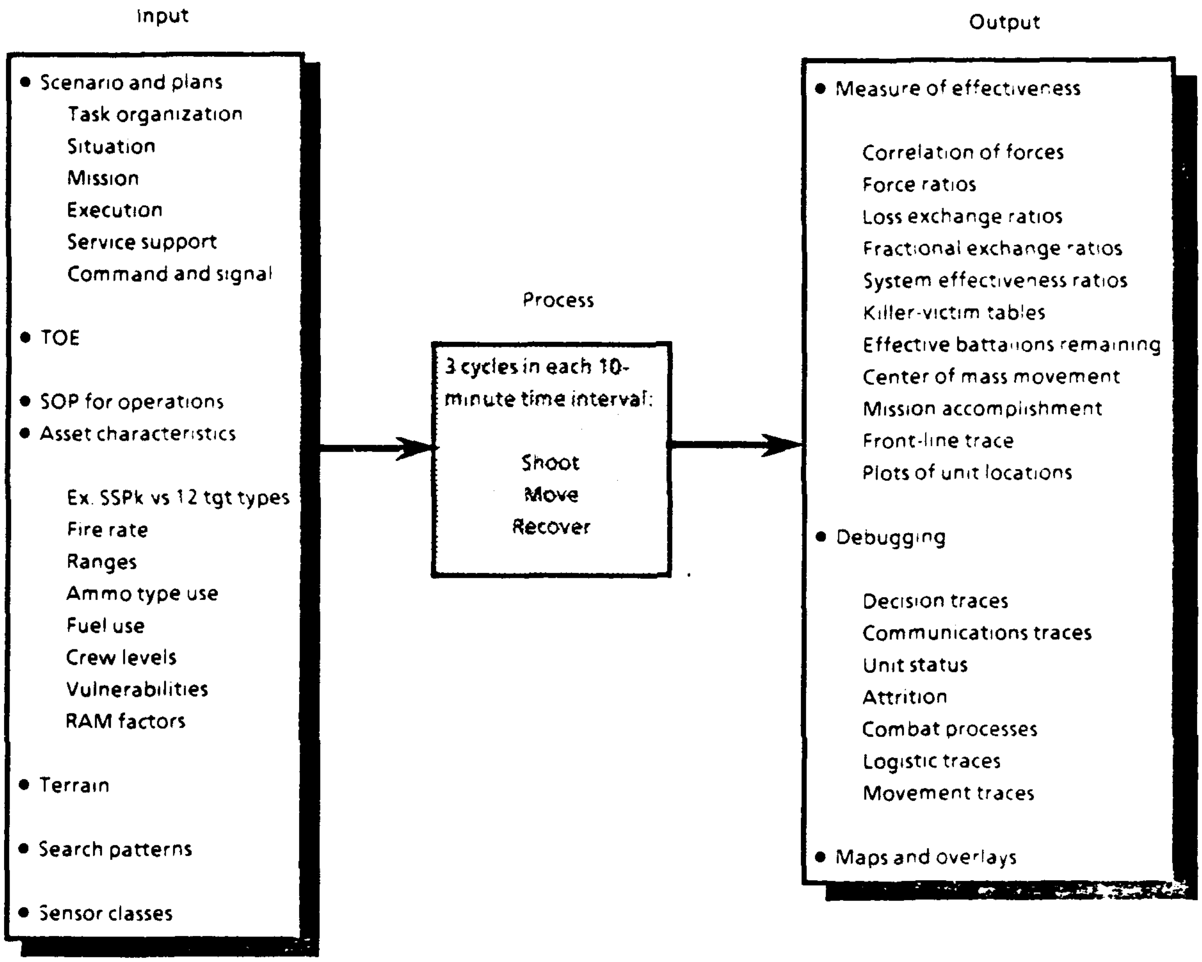


Figure 4-1. The CORBAN Model

d. Implementation. During VAA Phase II, the CORBAN Model was transferred from the VAX computer and was run on a network of SUN work stations. This transfer allowed several CORBAN runs to be made simultaneously, which shortened the time needed to complete sets of runs. This, together with the development of the deterministic version of CORBAN, which requires only one replication per excursion, reduced the amount of time needed to complete the combat simulations. Otherwise, it would have been impossible to have the combat results by the time they were needed. Even so, the decision was made to eliminate the series of NEA scenarios and use only one Contingency and one Stressful Scenario. This decision was made because NEA required an entirely new base case to be developed, and not enough time was available to accomplish this task.

e. Systems Modeled

(1) The following is a list of VAA weapon systems that were modeled in CORBAN and for which results were obtained.

Year	Acronym	Name of system
1996	AAWS-M	Advanced Antitank Weapons System - Medium
1996	ADATS	Air Defense Antitank System
1996	Adv QUICKFIX	Advanced Quickfix Electronic Warfare System
1996	ARV	Armored Recovery Vehicle
1996	ATAS	.r-to-air STINGER
1996	AVENGER	AVENGER
1996	FMTV 2.5/5	Family of Medium Tactical Vehicles 2.5 Ton/5 Ton
1996	GBCS-L/H	Ground Based Common Sensor - Light/Heavy
1996	HAB	Heavy Assault Bridge
1996	HET	Heavy Equipment Transporter
1996	JSTARS	Joint Surveillance Target Attack Radar System
1996	M1A2	M1A2 Abrams Main Battle Tank
1996	MLRS SADARM	Multiple Launch Rocket System Sense and Destroy Armor
1996	PLS	Palletized Loading System
1996	TOW 2B	Tube-launched, Optically tracked, Wire Guided Missile 2B
1996	VEMASID	Vehicle Magnetic Signal Duplicator
1996	VOL Air	VOLCANO Multiple Delivery Mine System - Air
1996	VOL Gnd	VOLCANO Multiple Delivery Mine System - Ground
1996	WAM	Wide Area Mine
2001	155 ER	155mm Extended Range Round
2001	155 LtWt	155mm Light Weight Howitzer
2001	155 TGP	155mm Terminally Guided Projectile
2001	Adv Firefinder	Advanced Firefinder
2001	AGS	Armored Gun System
2001	AH-64 LB	Apache Attack Helicopter with LONGBOW
2001	AMS-H	Advanced Missile System - Heavy
2001	ATACMS II	Army Tactical Missile System Block II
2001	GBS	Ground Based Sensor
2001	LOSAT	Line of Sight Antitank
2001	MLRS TGW	Multiple Launch Rocket System Terminally Guided Weapon
2001	NLOS-AT	Nonline of Sight - Antitank
2001	RAH-66	Comanche Reconnaissance Attack Helicopter
2001	STINGRAY	STINGRAY Combat Protection System
2004	Adv SEMA	Advanced Special Electronic Mission Aircraft
2004	AFAS	Advanced Field Artillery System
2004	BLOCK III	Block III Main Battle Tank
2004	CMV	Combat Mobility Vehicle
2004	FARV-A	Future Armored Resupply Vehicle - Artillery
2004	FIFV	Future Infantry Fighting Vehicle
2004	RAH-66 LB	Comanche Reconnaissance Attack Helicopter with LONGBOW

(2) A description of the major aspects of each weapon system, as modeled in CORBAN, is found in Appendix F, Volume II, of this report.

(3) Note that several additional systems were included in the original list. However, they were ultimately omitted because they were found to be difficult to model or were eliminated from procurement consideration prior to the beginning of the study.

f. Simulation Results

(1) Results by individual run have no meaning, since each run is an independent mix of systems. One run cannot be compared meaningfully with another. The run results must be processed by the RSM to obtain system results; see paragraph 4-7.

g. Lessons Learned and Work for Phase III

(1) Probably the most important lesson learned is to begin modeling and testing the systems early. There is no doubt that some anomalous results were caused by unusual adverse synergistic effects. Because each run has as many as 40 new systems, it is impossible to identify causal effects with surety. Verification of input data allows the identification of data and modeling errors in some cases, and in others, a better way to model certain systems the system in question is required. With enough time, a more scientific approach could be undertaken. Each system could be modeled and tested by itself in a full-up scenario, then placed in a combined arms context to measure positive and negative effects. Finally, the approved scenario could be used to test each system. It would be impossible to run each system with every other system individually, but one model of the final scenario could be set aside, and each system could be added and run one by one. Each run could be compared with preceding runs to identify negative impacts. This procedure would reduce the incidence of data and modeling errors in the final record runs of the model.

(2) No doubt the second most import lesson is to point out the need to put all of the records necessary to model systems into an input data base management system. The data base management system's own language could be used to perform some simple data checks. Software could then be written to automatically build the CORBAN run files from the data base of systems. Other programs could be written to build all the runs necessary to execute an experiment by reading in an experimental design matrix.

4-2. MEASURES OF EFFECTIVENESS (MOE). The following MOE were used to measure systems' contributions to combat effectiveness.

a. Fractional Exchange Ratio (FER) - measures the fractional Red losses compared to fractional Blue forces. FER is computed as follows:

$$FER = \frac{Red\ System\ Losses/Red\ Systems\ Started}{Blue\ System\ Losses/Blue\ Systems\ Started} \qquad (1)$$

The intent was for FER to measure how well Red is killed by Blue.

b. Blue Force Surviving (BFS) - determines the percentage of Blue strength remaining. Blue strength is determined by the number of items times their weight, compared to the beginning strength of the Blue Forces. Blue strength is computed as follows:

$$\textit{Blue strength} = \sum_{i=1}^{n} \left(\textit{Number of Blue system surviving}_i * \textit{System's weight}_i \right) \qquad (2)$$

where i = the system number.

The system weight is the effectiveness index parameter from CORBAN (see the CORBAN User's Guide for details). This MOE was used to measure the survivability force as different combinations of systems were employed.

4-3. INTRODUCTION TO RESPONSE SURFACE METHODOLOGY (RSM). A detailed explanation of RSM and the use of experimental design can be found in the CAA Technical Paper, Experimental Design with Combat Models (XD COMBAT), CAA-TP-92-9.

a. The requirement exists to determine the combat contribution of each weapon system to the outcome of the battle as measured by the explicit MOE. A common method of accomplishing this task is to establish a baseline case which includes no new system, then to add or substitute each new weapon system one at a time, measuring the changes in combat effectiveness. Alternatively, a base case can be established which includes all new weapon systems, and then deleting one in each excursion, measuring the changes in simulation outcome. These changes from the baseline case measure the contribution of a weapon system. In VAA Phase I, the latter technique was used. While this method measures the contribution of each individual system, it does not allow for the determination of the combined effect of weapon systems mixes, i.e., if an attack helicopter raises the value of an MOE by "x" and a tank raises the value by "y" as individual substitutions, then it is not true that if both systems are present, the resulting improvement would be "x + y."

b. The ideal method for determining the optimal mix of new systems would be to explore all possible combinations. This method would find the combination of systems that yields the greatest increase in the MOE values. While this method is practical for situations where the number of systems to be evaluated is small, the number of combinations grows quickly as the number of such systems increases. For 3 systems, there are 2^3 or 8 combinations. If one had to explore every combination of 40 different systems, the number of potential runs would be 2^{40}, or 109.9 billion runs.

c. RSM represents a compromise between the process of replacing weapons one at a time and the ideal solution of examining every combination. This compromise is a fractional design, meaning that a specific subset of the combinations is used. The subset of combinations of systems to be examined is determined using a particular experimental design. The resulting "design matrix" varies the combinations in an efficient manner so that a general linear model can be built to forecast the effects of the systems with respect to the outputs. A set of coefficients is computed which is the mean or average contribution given the new weapon system. These coefficients can then be used in an additive estimate.

4-4. USE OF RSM

a. "RSM comprises a group of statistical techniques for empirical model building and model exploitation. By careful design and analysis of experiments, it seeks to relate a 'response,' or output variable to the levels of a number of 'predictors,' or input variables, that affect it." As illustrated in Figure 4-2, the output values from CORBAN, namely, the specified MOE, are functions of the various input values. The purpose of RSM is to identify these functional relationships.

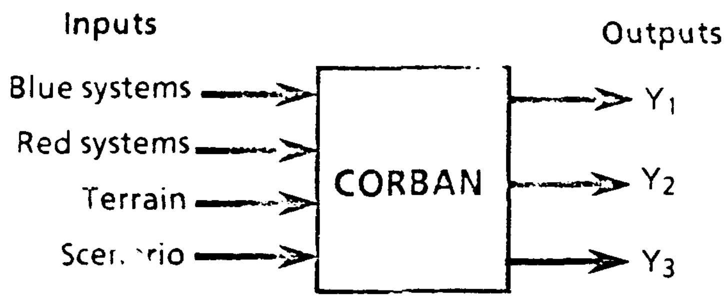


Figure 4-2. CORBAN with All the Inputs

b. In VAA, the Red systems, the terrain, and the scenario input variables are held constant and the Blue systems that will be studied are varied. Thus, the inputs into the black box are reduced to a more manageable size. This reduction is as illustrated in Figure 4-3.

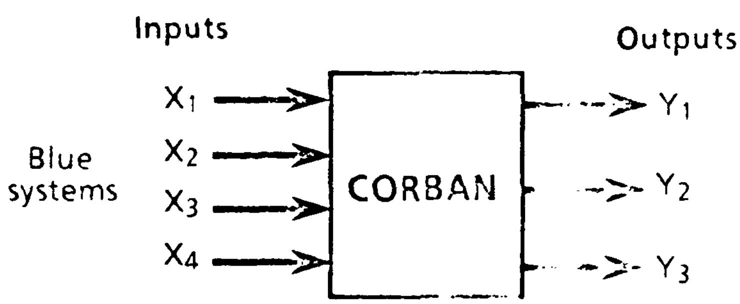


Figure 4-3. Controlling only the Desired Inputs

c. A general linear model is used to estimate an output or dependent variable, Y, whose mean is a function of one or more independent variables (x_1, x_2, etc.). The general linear model has the form:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n \qquad (3)$$

where b_i is the individual average response of the independent variables on Y. In matrix form, the general linear model appears as:

$$Y = XB \tag{4}$$

In the matrix format, Y is a vector of the model results for a particular MOE. Each element of the vector is the value corresponding to a particular excursion. B represents the vector of b_is, with b_0 representing the effect of the base case weapons, and b_1 through b_r are the effects of systems 1 through r in the excursions. Finally, X is the design matrix of binary independent variables whose construction is described below. This mathematical model isolates only the presence of main effects without considering any interaction effects.

d. Plackett-Burman designs are useful when the problem of determining the main effects with maximum precision is reduced to a combinatorial problem. They are useful when the problem has only two-level factors, i.e., when there are low and high variable settings or binary (0, 1) variables. In VAA, the systems being considered for procurement are the factors. A "1" represents the presence, in the appropriate quantities for the modeled force structure, in the excursion. A "0" indicates that none of the items are played in that excursion. Plackett-Burman's method specifies the construction of the design matrix, X. This matrix represents a map of all of the independent variables' values for each computer run. Each row corresponds to a specific computer run and each column corresponds to a different factor.

e. To illustrate this coding scheme, consider the following two cases. The first case involves a new system replacing an existing system. An example of this case would be the Advanced Antitank Weapons System Medium (AAWS-M) replacing the DRAGON. In excursions where soldiers are equipped with the AAWS-M, a 1 would be entered in the design matrix. In excursions where the DRAGON is used, a 0 would appear.

f. The second case involves a new system that does not replace an existing system. The Joint Surveillance Target Attack Radar System (JSTARS) would be such a system. In this case, a 1 would indicate the presence of the new system, while a 0 would denote its absence.

g. Once the design matrix is formed, each combat model excursion is performed using the systems specified as in the design; and in turn, the outputs (i.e., BFS or FER) are produced forming the Y vector. The coefficients (elements of B) for the linear model are obtained by matrix algebra, then:

$$XB = Y \tag{5}$$

To solve for B, there are two options. If a full Plackett-Burman matrix is used without deleting any columns such that X is of full rank, then:

$$B = X^{-1}Y \tag{6}$$

If there is a need or desire to use a reduced matrix, then use the standard formula for solving a general linear model:

$$B = (X^T X)^{-1} X^T Y \tag{7}$$

The above matrix manipulation can be done on spreadsheets, IMSL routines, FORTRAN programs, SPSS, BMDP, or other statistical programs.

Example: In this example, the seven weapon systems were examined. These systems are weapons 1 to 4, field artillery (FA) weapons 5 and 6, and attack helicopter 7. After setting up the experimental design, conduct a combat simulation including those systems in a row which have a 1 in the design matrix. The result from each combination is recorded as a value for the MOE of interest. Since the X matrix is full rank, use equation 4-6.

$$\begin{array}{ccccc} & \textit{Design matrix} & & \textit{MOE} & \textit{Run \#} \\ X = & \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} & Y = & \begin{bmatrix} 23 \\ 45 \\ 24 \\ 34 \\ 56 \\ 67 \\ 78 \\ 3 \end{bmatrix} & \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{matrix} \end{array}$$

$$X^{-1} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0.25 & -0.25 & -0.25 & 0.25 & -0.25 & 0.25 & 0.25 & -0.25 \\ 0.25 & 0.25 & -0.25 & -0.25 & 0.25 & -0.25 & 0.25 & -0.25 \\ 0.25 & 0.25 & 0.25 & -0.25 & -0.25 & 0.25 & -0.25 & -0.25 \\ -0.25 & 0.25 & 0.25 & 0.25 & -0.25 & -0.25 & 0.25 & -0.25 \\ 0.25 & -0.25 & 0.25 & 0.25 & 0.25 & -0.25 & -0.25 & -0.25 \\ -0.25 & 0.25 & -0.25 & 0.25 & 0.25 & 0.25 & -0.25 & -0.25 \\ -0.25 & -0.25 & 0.25 & -0.25 & 0.25 & 0.25 & 0.25 & -0.25 \end{bmatrix} \tag{8}$$

$$B = X^{-1} Y$$

$$B = \begin{bmatrix} 3 \\ 18.5 \\ 18.5 \\ -3 \\ 8 \\ -14 \\ 18.5 \\ 30 \end{bmatrix} \begin{matrix} \textit{Mean value of the base case} \\ \textit{Weapon 1} \\ \textit{Weapon 2} \\ \textit{Weapon 3} \\ \textit{Weapon 4} \\ \textit{Field artillery 5} \\ \textit{Field artillery 6} \\ \textit{Attack helicopter 7} \end{matrix}$$

The equation for the predicted MOE based on the above results is:

$$MOE = 3 + 18.5\,WPN1 + 18.5\,WPN2 - 3\,WPN3 + 8\,WPN4 - 14\,FA5 + 18.5\,FA6 + 30\,ATKH7$$

where each system is either 1 or 0.

4-5. MEANING OF VALUES

a. While the general linear model is normally used for fitting a regression line among quantitative variables, it can be used with qualitative variables as well. The estimator b_0 is the measure of worth of the base case weapons. The estimators b_1 through b_r represent the contribution of individual systems to the change in the corps-level MOE (i.e., FER and BFS). "These coefficients are often called differential intercept coefficients because they reveal by how much the value of the intercept term of the category that receives the value 1 differs from the intercept coefficient of the category that receives the value 0. The category that receives the value zero is often referred to as the base or comparison category."

b. Another advantage of the above formulation is that the general linear model can be used to evaluate different force packages or mixes of systems without rerunning CORBAN. The linear model can then be used to give an estimate of the values of FER and BFS for the new combinations of systems without conducting additional simulation runs.

4-6. PROBLEMS USING THIS TECHNIQUE

a. This procedure is not a cure for input errors and intense weapon system interactions, nor does it immediately help to explain counterintuitive results. Thorough analysis is still required to check the answers, and then serious thought is needed to interpret the results.

b. When this methodology was first used in the VAA Study, the discovery of input errors was difficult. When the traditional method of combat modeling is used, only one system at a time is adjusted from the base case. The modelers can then easily compare the results from their excursions to the base case and determine the differences and find any errors. It is much more difficult to find modeling errors in an experimental design when there are many different new systems in each run. Once major errors are discovered, rerunning the simulation may be required to correct the error.

c. A major concern arose when systems' coefficients were negative. Intuition tells the analyst that the replacement of an old system with a vastly superior system should not result in a decrease in capability. An examination of the systems then showed unnoticed modeling data problems with the negative systems. Examples are search patterns larger than the arrays set up to store them, firing rates set to zero, or an incorrect portrayal of the weapon. The methodology has not yet, in its use in VAA, produced a result that was worse for a clearly superior system when the input data for the respective new and old systems were correct.

d. To assist in error checking, other summary or intermediate statistics were used to find problems. An example is the number of losses for each side. For instance, if the FER for a system is negative, the major components of FER, the number of Red losses, and the number of Blue losses are examined. The regression was applied to these statistics, and interesting discoveries could be made. The presence of some weapons was linked to Blue experiencing more losses during these runs. Calculations showed that it was the increase of Blue losses that made the system's FER turn negative. This technique helped lead to discovering the reason why there were more Blue losses. An example is when the Advanced Missile System-Heavy (AMS-H) and tube-launched, optically tracked, wire guided missile 2B (TOW 2B) missiles killed less smaller Red weapons (i.e., antitank guided missiles (ATGMs)) than the TOW 2A which, in turn, killed more Blue systems. The solution was to model the Bradley chain gun.

e. In some cases, an interaction between two systems occurs. This interaction can be a synergism between two systems that greatly increases their ability. A pairing of a long range sensor and a long-range missile is an example of a possible synergistic interaction. The interaction could also decrease the systems' MOE contribution, such as two long-range weapons that, when together, compete for the same targets. A solution to this problem is called a "foldover" design that isolates the main effects of the interested systems. The cost of this "foldover" design is to double the number of computer runs. Other designs to specifically measure interactions are available, but their cost in the number of computer runs is prohibitive except in problems with only a limited number of independent variables.

f. Interpretation of combat results has never been easy. Time and thought still need to be invested to determine why a system is doing so poorly, or doing so well, and then to present the results to the decisionmakers. Decisionmakers need to understand the reasons for an answer, and RSM may make it more difficult for the modeler to explain the results. In this particular situation, a data base system is invaluable to manipulate the large amount of data needed to perform these analyses. Explaining and verifying counterintuitive results is a difficult and tedious process.

4-7. RESULTS FROM RSM. The following system results were obtained for FER and BFS for each scenario/year group combination. These values are additive for only that particular scenario/year MOE combination. For instance, to forecast the BFS in the Contingency 96 Scenario for a particular system mix, one added the intercept term and then all other values for specific VAA systems.

a. Table 4-1 contains the Contingency 96 Scenario results.

Table 4-1. RSM Results for Contingency 96 Scenario
(contribution of systems to MOE)

Systems	1996		2001		2008	
	FER	BFS	FER	BFS	FER	BFS
INTERCEPT	2.378	0.750	2.458	0.805	2.842	0.825
AAWS-M	0.275	0.023	-0.018	0.003	-0.119	0.000
ADATS	0.263	0.017	1.779	0.033	1.610	0.023
ADV QUICKFIX	0.200	0.022	-0.048	-0.002	0.152	0.009
ARV	-0.002	-0.002	0.100	0.004	-0.235	-0.004
ATAS	0.170	0.011	0.351	0.008	-0.079	-0.001
AVENGER*	NA	NA	NA	NA	NA	NA
FMTV 2.5/5	-0.148	-0.009	-0.020	0.002	0.332	0.011
GBCS-L/H	0.068	0.004	-0.015	0.001	0.447	0.012
HAB	0.159	0.006	0.341	0.011	0.128	0.004
HET	-0.037	0.002	0.024	0.006	0.175	0.010
JSTARS	0.193	0.014	0.029	0.001	0.025	0.000
M1A2	-0.058	0.000	0.500	0.014	-0.588	-0.009
SADARM	0.120	0.011	0.686	0.019	0.266	0.006
PLS	0.067	0.011	-0.058	0.001	-0.088	-0.001
TOW 2B	-0.030	-0.001	-0.093	0.002	0.193	0.002
VEMASID	-0.063	-0.001	-0.056	0.001	0.053	0.001
VOL Air	0.207	0.009	-0.023	0.000	0.226	0.012
VOL Gnd	-0.106	-0.002	-0.004	0.002	-0.037	0.000
WAM	0.496	0.036	0.235	0.013	0.076	0.005
155 ER			-0.009	0.003	0.047	0.000
155 LtWt			0.116	0.006	0.138	0.003
155 TGP			0.176	0.006	0.233	0.009
ADV FIREFINDER			0.109	0.003	-0.078	-0.001
AGS			-0.325	-0.005	-0.377	-0.003
AH-64 LB			0.353	0.011	0.418	0.011
AMS-H			-0.116	0.001	-0.129	-0.002
ATACMS II			0.122	0.008	-0.251	-0.002
GBS			0.356	0.009	0.100	-0.002
LOSAT			-0.193	0.007	0.316	0.005
MLRS TGW			0.662	0.020	0.631	0.019
NLOS-AT			0.636	0.016	0.045	0.003
RAH-66			1.563	0.036	0.835	0.024
STINGRAY			-0.056	0.003	0.081	0.005
Adv SEMA					-0.136	-0.002
AFAS					0.309	0.012
BLOCK III					0.185	0.009
CMV					-0.287	-0.005
FARV-A					0.090	0.006
FIFV					0.685	0.016
RAH-66 LB					0.998	0.024

*Already fielded to all units in this scenario.

b. The following summary observations are made on the Contingency Scenario runs.

(1) Two major problems were found in Contingency 96 runs and corrected for all follow-on scenarios. The wide area mine system (WAM) was being used three different ways, instead of two, and the Bradley chain gun was not being modeled to portray kills against "lesser" targets. WAM should have been played consistently "in" or "out" of the generic minefields; but when the VOLCANO Multiple Delivery Mine System-Air (VOL Air) and WAM were both present, WAM went into a third minefield belt. This caused VOL Air to receive a higher coefficient than it should and the Air Volcano has been manually corrected downward. Another problem noted was that the Bradley chain gun used only the antitank (AT) missile. This caused problems for the TOW 2B and AMS-H as the failure of the Bradley to kill ATGM ar 1 "lesser" targets were rolled into the AT missiles.

(2) A minor correction between 1996 and the later years was an adjustment to make Blue counterbattery targeting work better.

(3) One problem discovered after all the runs were made has to do with the improvement of the Blue base cases in the latter years, even while the Red modernized. It was discovered that while Red upgraded their tanks in each year, the capabilities of these tanks actually decreased due to a data input error with the older tanks. This, along with the changes described above, may be the reason why the base Blue force did better in 2004 and 2001 than in 1996. This problem was corrected.

(4) The number of Red kills by Blue seems to hit a threshold (approximately 5,000 kills) and cannot get much higher. The reason may be that Blue consistently destroyed all Red forces forward of the Blue objective. The significant change between simulation runs is the number of Blue causalities. Usually, the highest number of Blue casualties is in the base case run, with the excursions being much lower. This causes an interesting effect on the FER and BFS. Since both MOE use Blue causalities as an intermediate part of the calculations and Blue losses is the most volatile part in the runs, both FER and BFS are highly correlated. Generally, this means that the rank-ordering given by one MOE will be almost the same as rank-ordering done by the other MOE. This correlation is so high that one MOE is a linear predictor of the other MOE.

c. The following summary observations are made on the Stressful Scenario runs.

(1) Red smart artillery was a prominent killer. Likewise, improvements in Blue counterbattery assets lessened the Red effects.

(2) Blue helicopters, while still potent, suffered greatly from Red air defense assets.

(3) Improvements in close combat systems became much more important in this scenario. Target stealing did not appear to be as much of a problem, as this was a very target-rich environment.

(4) Blue never achieved overwhelming superiority against Red.

d. The following individual system problems were discovered in all scenarios, and correction experimental designs were performed.

(1) Sense and destroy armor (SADARM): three instead of six submunitions, targeting data not optimally set, and orders improperly set so that SADARM would not fire when the multiple launch rocket system terminally guided weapon (MLRS TGW) was present in the same excursion.

(2) Nonline of sight (NLOS): improper data set up caused it to fail to fire.

(3) Line of sight antitank (LOSAT): improper target class.

(4) Armored Gun System (AGS): defaulted to an improper role during the counterattack.

e. Table 4-2 contains the Stressful Scenario case results.

f. The results of the Stressful Scenario are a marked contrast to the Contingency Scenario. The Blue forces, in the Contingency Scenario, had achieved victory consistently. In the Stressful Scenario, Blue seldom achieved victory. When comparing the experimental design runs MOE for Contingency, there is a marked increase of MOE values above the base case. This pattern appears linear and well-behaved. Stressful experimental design runs do not have linear or well-behaved patterns. Both Red and Blue losses vary greatly, as do the MOE.

Table 4-2. Stressful Scenario Results
(contribution of systems to MOE)

System	1996 FER	1996 BFS	2001 FER	2001 BFS	2008 FER	2008 BFS
INTERCEPT	0.676	0.563	0.689	0.486	0.688	0.454
AAWS-M	0.041	0.016	0.033	-0.013	0.041	0.035
ADATS	-0.002	0.001	0.062	0.032	-0.058	-0.017
ADV QUICKFIX	0.015	-0.019	0.043	-0.009	-0.046	-0.030
ARV	-0.014	0.011	0.016	0.007	-0.021	0.001
ATAS	0.009	-0.016	-0.004	-0.001	-0.063	-0.015
AVENGER	-0.030	-0.016	-0.036	0.016	0.051	0.000
FMTV 2.5/5	-0.013	0.011	-0.002	-0.023	0.000	-0.013
GBCS L/H	-0.026	-0.045	0.007	0.017	0.001	-0.006
HAB	0.022	0.026	0.034	0.026	0.036	0.024
HET	-0.025	0.009	-0.006	0.001	-0.018	-0.003
JSTARS	0.016	-0.020	0.002	0.013	0.038	0.016
M1A2	0.041	-0.004	0.064	0.012	0.015	0.032
SADARM	-0.030	-0.027	0.216	0.025	0.278	0.056
PLS	0.000	-0.011	0.035	-0.005	0.067	0.018
TOW 2B	0.009	0.014	-0.014	0.006	-0.026	0.037
VEMASID	0.027	0.004	-0.006	-0.023	0.002	0.009
VOL Air	-0.010	0.009	-0.009	-0.013	0.052	-0.012
VOL Gnd	0.003	0.006	0.006	-0.005	-0.043	-0.010
WAM	0.134	-0.024	0.047	0.008	0.040	0.016
155 ER			0.027	0.020	0.028	0.004
155 LtWt			-0.006	-0.011	0.034	0.004
155 TGP			-0.016	-0.019	-0.036	-0.024
ADV FIREFINDER			0.043	0.020	-0.006	0.004
AGS*			NA		NA	
AH-64 LB			0.093	-0.006	0.174	0.033
AMS-H			0.029	0.010	0.019	0.006
ATACMS II			-0.013	-0.008	0.003	0.013
GBS			0.047	0.026	0.098	0.022
LOSAT			0.128	0.023	0.064	0.012
MLRS TGW			0.026	-0.011	0.036	-0.008
NLOS-AT			-0.048	0.011	-0.262	-0.064
RAH-66			0.019	-0.013	0.157	0.011
STINGRAY			0.011	-0.010	0.008	0.007
Adv SEMA					-0.008	-0.004
AFAS					0.024	0.001
BLOCK III					0.218	0.042
CMV					-0.098	-0.012
FARV-A					0.024	-0.006
FIFV					0.410	0.083
RAH-66 LB					0.212	0.019

*None played in this scenario because none of these Blue units are authorized the Armored Gun System.

CHAPTER 5

IMPLICIT MEASURES OF VALUE

5-1. GENERAL. The implicit effectiveness portion of VAA encompasses the identification, gathering, and synthesis of information necessary to provide the appropriate weighting factors for use in calculating predicted marginal values for each of the systems. The weighting factors will be used in a multiattribute decisionmaking environment (TOPSIS) in order to generate these values. The marginal values will be used as coefficients of an objective function within a mixed integer linear programming model (VALOR).

5-2. METHODOLOGICAL OVERVIEW. The principal notion involved in the development and acquisition of these weighting factors involves the use of the AHP originated by Professor Thomas L. Saaty in the early 1970s. In this approach, criteria are identified at one or several levels of a hierarchical framework, and a pairwise comparison technique is used, iteratively entering the opinion of the surveyee as to the degree one criteria is more important/ influential than the other. In doing so, the surveyee completes a positive, reciprocal matrix of these opinions. By calculating the eigen or characteristic vector of the matrix, each of the criterion at the current level of the hierarchy is associated with a "proportion" or contribution of the criterion to the next higher level entry of the hierarchy. However, unlike other techniques of multicriteria comparison, the AHP method provides factors which relate to each other, not only in magnitude (effectively providing an ordinal ranking), but also in proportion or relative magnitude to each other. It is this characteristic of proportionality that was essential for use in the later optimization phase of VAA.

5-3. AHP HISTORY. Professor Thomas L. Saaty of the University of Pittsburgh is most noted for his groundbreaking DOD and State Department work in the 1970s where his AHP principles were first applied. His first book in 1980, The Analytic Hierarchy Process, was well received and was followed by numerous additional journal publications: Socio-Economic Planning Sciences (12/86), Mathematical Modeling (08/87), and European Journal of Operations Research (08/90).

5-4. CHARACTERISTICS OF AHP. The theory behind AHP is rich in substance, but the attributes which characterize simply the elemental qualities of the methodology are given below:

Useful for comparing multiple level/criteria options
Hierarchical framework
Characterized by pairwise comparison
Scale of input values between 1/9th and 9
Can use subjective as well as objective data

5-5. AHP ASSUMPTIONS (REWORDED AXIOMS). The assumptions of AHP provide an excellent framework for an introduction to the technique. It is assumed that they are preceded with a problem involving multiple alternatives to be compared and a defined set of criteria at one or more levels with which to base the comparison.

a. No alternative has infinite importance. If an alternative had infinite value, then it is not an alternative but rather an inviolate condition and comparison would not be necessary.

b. No alternative has zero importance. Similar to subparagraph a above, any alternative having zero importance is not an alternative and is immediately dominated by all alternatives which have any importance at all.

c. Importance ranges from equal (1) to absolute (9). Although controversial, the graduations of the preference scale consisting of the integers 1 to 9 form the yardstick of the methodology. A number of related efforts have shown that there is little to be gained by additional graduations and that the value of 1 associated with equality is a naturally appealing notion. The textual descriptions of the values on the scale are subject to revision based upon the context of the criterion, but the increasing value/importance as the numbers increase is a necessity.

d. Set of alternatives is not subject to change. Because the technique involves the combining of relative importance assessments, the removal or introduction of an alternative can have a significant impact on the final results. The partitioning of total value is sensitive to the number of partitions--change this number and the process is apt to require a complete reassessment.

e. Importance is reciprocal between any two alternatives. The relative importance of one alternative over another is a shared ratio relation. If A is more important than B by a measure of 5, then B is said to be 1/5th as important as A by implication. This condition allows for the method to minimize the number of comparisons as the reverse ordering of the pair of alternatives has an associated value which is the reciprocal of the first. Additionally, an alternative has equal importance with itself. In combination, for a problem with n alternatives, these two facts generate a requirement to consider only $(n * (n - 1)) * .5$ pairwise evaluations, a significant savings over $n * n$ comparisons.

f. All criteria/alternatives impacting on a problem are specifically represented or excluded. This is the most difficult aspect of the construction of the hierarchy. It requires that at any level in the hierarchy where there are competing alternatives or criteria, the items comprise a set of possibilities which completely covers the scope of that particular level of the hierarchy. In this way, this assumption relates to subparagraph d above as it defines the number of partitions occurring at a given level. A more subtle implication associated with this assumption is one which requires maximum independence between criteria/alternatives. The better the distinction between alternatives, the easier the construction of the hierarchy becomes.

5-6. AHP THEORY AND MATHEMATICS. With the completion of the pairwise comparison, the real work begins in deriving the respective weights for the criteria/alternatives at each level of the hierarchy. The evaluations of each pairwise comparison and its reciprocal represent components of a system of relationships which can conveniently be portrayed as a matrix with several important characteristics. The first characteristic is that all comparisons of an alternative with itself equal 1 and form a diagonal of 1's. Second, all elements off this diagonal are either between 1 and 9 or between 1/2 and 1/9 inclusive. At this point, there exists what is called a positive reciprocal matrix which retains a number of useful characteristics itself. The matrix can now be manipulated to extract the right eigenvector. Also called the characteristic vector, the eigenvector represents an ordered array of values which are associated with the system of relationships found

within the matrix. In particular, the array is associated with one characteristic value (eigenvalue) which is the largest of all n eigenvalues. The calculations associated with the derivation of the eigenvector are generally tedious and complex. Saaty often discusses a number of procedures of increasing accuracy of estimating these values but ascribes to the most accurate method of that of the following expression:

$$\lim_{k \to \infty} A^k e (e^T A^k e)^{-1}$$

with $e^T = (1, 1, ..., 1)$ or the transpose of a column vector of 1's and A represents the positive, reciprocal matrix described earlier. The term $A^k e$ effectively produces a vector of row sums of this A^k matrix while the remaining portion of the expression, $(e^T A^k e)^{-1}$, generates a scaler associated with the sum of all the matrix A^k entries. While in theory, the values of the resulting vector are accurate only in the limit, in practical terms, the values seem to stabilize to 4 or 5 decimal places at about $k = 8$.

5-7. CONSISTENCY. In addition to the final weighting values for the alternatives, the AHP methodology, unlike many multiattribute methods, provides a measure of inconsistency in the form of a consistency ratio (CR). In a broader sense, it is obvious why consistency would be of interest in general for an application of multiple comparisons. But because AHP in principle is sensitive to the consistency of inputs, a mathematical derivation of a measure of consistency is desirable.

a. General Consistency. A simple decomposition of consistency would include two general types which can be called ordinal and technical consistency. Ordinal consistency (also called transitivity) is that condition in which if A is considered more important than B and B is considered more important than C, by implication, A must be more important than C. If VAA was only concerned with a rank-ordering of alternatives, a method focusing on ordinal consistency would be sufficient. However, relative magnitude or proportion is critical to the use of the resulting weights in the optimization, and so technical consistency is also important. Technical consistency can be analogized thusly: if A is 3 times as important as B and B is 2 times as important as C, A must be 6 times as important as C. It is clear that during the course of a large pairwise comparison survey, perfect consistency of both types would be ideal. It is also clear (both from Saaty's and the study team's experience) that all surveyees demonstrate inconsistencies to some degree. The ability to quantify this consistency or lack thereof is one of beneficial facets of AHP: the consistency ratio.

b. Consistency Ratio. The consistency ratio is a ratio of an input matrix dependent index called the consistency index (CI) and an index of a notional average matrix. Both indices are also ratios which are based on the assumption that a perfectly consistent input matrix has a max eigenvalue equal to the number of alternatives. When the difference is between the max eigenvalue and the number of alternatives is standardized by dividing by the degrees of freedom (n - 1), the resulting value is theorized to represent an index of the measurable consistency. In mathematical terms,

$$CI = (\lambda_{max} - n)/(n - 1),$$

with λ_{max} being the max eigenvalue. The max eigenvalue is calculated for the input matrix of the responses to the survey. Once obtained, the CI is divided by an average CI of a large quantity of input matrices of the same order as the current problem which were constructed with random entries. The ultimate effect of this division is the generation of a ratio which reflects how closely the input corresponds with a survey completed with totally random responses. As the ideal index is 0 and increases with deviations from the ideal, the consistency ratio is probably more aptly named the inconsistency ratio.

c. Acceptable Inconsistency. According to Saaty, a convention of rejecting surveys having a CR in excess of 0.1 has met with general acceptance. In the VAA experience, the aggregated survey inputs proved to be significantly free of inconsistencies, generally having CRs on the order of 0.03. This is attributable to a serendipitous factor of using a geometric mean technique of survey aggregation (which deserves further study). It should be noted that the individual surveys were not as consistent, and techniques for assisting the survey taker in maintaining consistency would be of benefit. In summary, the excellent CRs provided an additional sense of credibility to the final weights.

5-8. HIERARCHY. The hierarchy constructed for VAA II was fundamentally different, both from the standard AHP as well as that used in VAA I, in response to the sponsor/user requested desire to see how the systems fared in various perspectives of performance or benefit. Saaty's hierarchy was characterized by multiplicative branching as one progressed out from the root, topmost, or level 1 (goal) of the hierarchy, each node having a fixed number of contributing elements. The design of the hierarchy in VAA I also mirrored this structure. In contrast, the hierarchical tree shown in Figure 5-1 allows for evaluation of different values for given systems if, for example, interest was focused on only a selected three elements in the third or fourth level (VAA coefficient = level 1) at the exclusion of the others. It should be pointed out that the surveys and AHP application stop short of the systems level where a multicriteria decisionmaking tool, TOPSIS, is used. This tool and its use are described in Chapter 6.

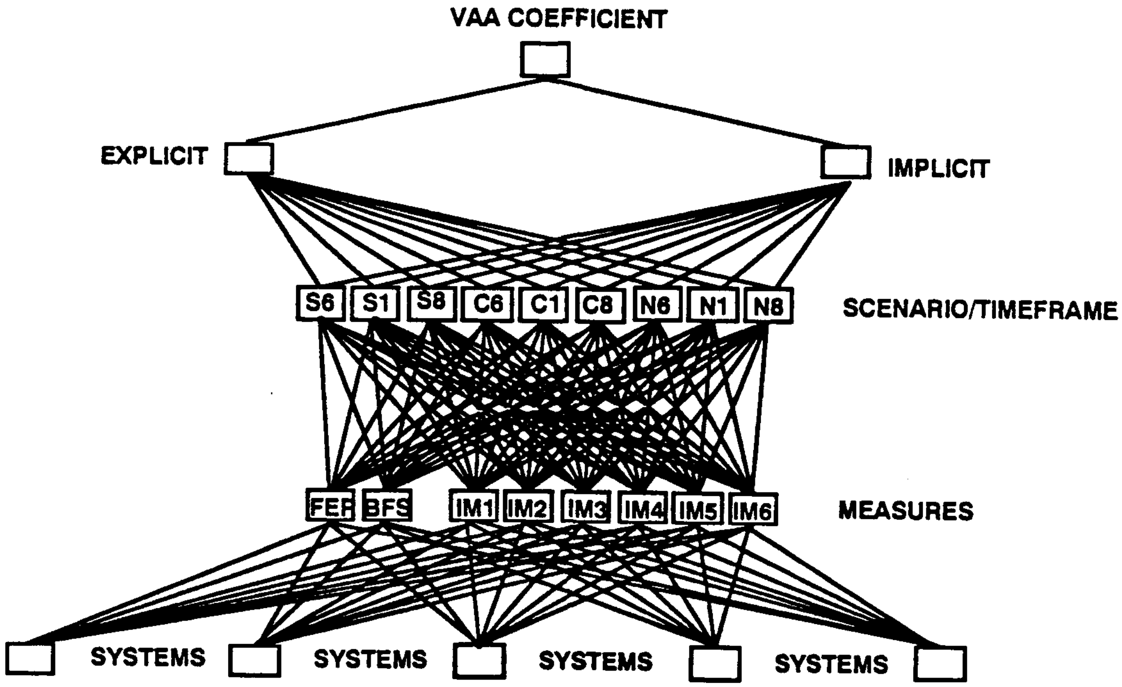


Figure 5-1. Hierarchical Tree

a. Implicit versus Explicit. The second level of the hierarchy consists of the division of system value into two effectiveness components, explicit and implicit. Explicit measures of effectiveness can be defined as factors that measure the worth of the system/program in terms of its contribution to overall force effectiveness and that can be directly and objectively computed (e.g., combat simulation results). Implicit measures of effectiveness are factors that affect the decisionmaking process, but are only subjectively measurable (e.g., political risk).

b. Timeframe and Scenario. VAA II is targeted toward the 1994-99 POM. It is consistent with this purpose to consider systems and programs which will potentially begin or expand their research, development, test, and evaluation (RDTE) outlays within this 5-year window. Additionally, the EPP was a consideration, providing an additional 8 years of interest. This prompted the need for a 13 + year look which was decomposed into three periods: near- (1996-2000), mid- (2001-2007), and far-term (2008 and beyond). Taking the first year of each period as representative, the chronological element of system value added was derived. Secondly, as the Army continues to be a worldwide deployable organization, a representative cross-section of tactical environments was desired. This, too, was divided into three areas: SWA, NEA, and Central Europe (post-CFE) which generally depicted the primary mid- and high-intensity combat scenarios under analysis in 1991. It was felt that each scenario represented sufficiently different enemy, environment, command, control, communications, computers, and intelligence (C4I), and deployability aspects to justify their inclusion while consciously minimizing the number of scenarios.

(1) In combination, the timeframes and scenarios composed an array of nine distinct time and location pairings which was believed would provide a suitable and comprehensive portrayal of the contributions of the systems. Additionally, it was felt that both the survey and the combat modeling would be capable of addressing this limited number of timeframe and scenario combinations.

(2) In the survey, the surveyees were asked to rate the relative importance of each pair of scenario-year combinations from the perspective of the need for programs/systems for inclusion in the 1994-99 POM development.

c. Secondary Factors. The six factors which comprised the qualitative or implicit portion of the hierarchy are defined below as they appeared in the survey briefing. The hypothetical examples which follow the factor definitions were used to exemplify some aspects of the notions associated with the factors and represent only analogies or situations having the characteristics previously defined.

(1) **Political Risk.** The subjective evaluation of the supportive or non-supportive attitude prevalent across the scope of public, Congressional, executive, and Army interest groups regarding the proposed program. Greater political risk is, by convention, less desirable.

HYPOTHETICAL EXAMPLES. Recent environmental accidents could generate public sentiment unfavorable to diesel-based ground vehicular systems. The Senate Armed Services Committee announces its fundamental distrust of millimeter wave technology. Major command commanders voice a unified desire to reduce types of vehicles.

(2) **Programmatics.** A subjective measure of the aspects of the proposed program which would influence program execution. Issues of complexity, flexibility, and executability of the program are considered. By convention, greater complexity of programmatics is less desirable.

HYPOTHETICAL EXAMPLES. A production cycle which includes maintaining a warm production line for 2 years midway through the program would be of increased complexity. The cost of increasing or decreasing production in years 3-5 are overwhelmingly unfavorable, hence indicating inflexibility.

(3) **Asset Versatility and Deployability.** A measure of the applicability of a program to multiple theaters of operation and their associated environments and requirements.

HYPOTHETICAL EXAMPLES. A program to develop a small unit snow vehicle would likely have limited versatility. Light vehicle-packed demineralization and desalinization equipment would likely have widespread versatility and deployability.

(4) **Operational and Technological Risk.** A subjective measure of the probability associated with a program meeting all of its stated performance criteria.

HYPOTHETICAL EXAMPLES. A program relying on superconductor technology portends considerable technological risk. A program which will only work if all of its 5,000 individual mechanical components have a minimum mean time between failures of 300 hours would likely be considered of high operational risk.

(5) **Criticality of Need as Related to Current Capability.** Program need is a subjective measure of the current status of the mission area or function associated with a program and the relative fraction of improvement that is expected.

HYPOTHETICAL EXAMPLES. A tank round which penetrates an additional 5mm of armor is not as critical as compared to nuclear, biological, and chemical (NBC) suit which could be recycled after wear with no loss of effectiveness if not exposed to contaminants.

(6) **Impact on Sustainability (combat).** A subjective measure of the collective effect of the system on other systems which support the effort of the force. By convention, a view toward lessening the sustainability burden and in turn enhancing the sustainability of the force will be used as being more desirable.

HYPOTHETICAL EXAMPLES. A vehicle system that is self-recovering or that carries substantially more of its primary munitions, effectively negating the need for support assets, would likely have a desirable impact, whereas a system requiring a new family of support vehicles and equipment would likely have a less desirable impact.

d. BFS versus FER Measures of Effectiveness. In this survey, which required only one input, a graduation of the "insightfulness" or utility of the two measures of effectiveness which could be explicitly measured was obtained. These two measures of effectiveness were readily available from the CORBAN simulation runs. The definitions of the two MOE were given.

(1) Blue force survivability (BFS) - a value of effective Blue force combat capability remaining upon termination of the simulated conflict.

(2) Fractional exchange ratio (FER) - the ratio of the proportion of Red systems lost to the proportion of Blue systems lost.

It was then noted that Blue force survivability is essentially a measure of simple survivability while fractional exchange ratio imparts a measure of the lethality of the Blue force with respect to the ratio of Blue to Red.

e. Feedback from Surveyees

(1) An aspect of the survey process which grew in significance as the surveys were conducted was the feedback or narrative comments provided by the participants. Originally, the study team was primarily concerned with technical aspects of the survey process and the VAA methodology. It was desired to obtain opinions of items specifically associated with the survey such as the mechanics of how the survey was conducted, the nature of the survey components, the definitions or vernacular used, suggestions for improvement, and, finally, the degree of confidence

in the comprehensive VAA program. It became increasingly obvious that the feedback exceeded the above dimensions.

(2) In order to promote the unrestrained evaluation of survey elements, each surveyee was informed of the nonattribution, close hold handling of the survey inputs (see Appendix D, VAA Read-ahead Memo). In this vein, under any circumstance will the identification of a surveyee, in association with his/her respective, completed survey, be disclosed. Efforts were made to strip identification from the data during the processing, and it is often impossible to reconstruct the associations. It is believed that this condition of the survey was the most constructive and brought out significantly more insight than the surveys themselves.

5-9. SURVEYS. Two surveys are used within the Value Added Analysis framework: decisionmaker surveys and subject matter expert (SME) surveys.

a. Decisionmaker Surveys

(1) Construction

(a) **Survey Mechanisms.** The central element for the execution of the survey is the pairwise comparison. In addition to a decision of which alternative is most important, the AHP requires a value judgment of the degree of greater importance. It was intrinsically important to include mechanisms which addressed both of these issues. A paper version of the survey was constructed, a sample of which is shown in Figure 5-2.

PROGRAMMATICS		**CRITICALITY OF NEED AS RELATED TO CURRENT CAPABLITY**
A subjective measure of the aspects of the proposed program which could influence program execution. Issues of complexity, flexibility, and executability of the program are considered. By convention, greater complexity of programmatics is less desirable.	VS.	Program need is a subjective measure of the current status of the mission area or function associated with a program and the relative fraction of improvement that is expected.

Absolute · Very Strong · Strong · Weak · Equal · Weak · Strong · Very Strong · Absolute

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Check the box which you believe is presently the best measure of the importance of the item on the left as compared to the item on the right.

Figure 5-2. Survey Sample

This appeared to be an adequate construction. The survey instrument displayed the two alternatives simultaneously. It provided a textual description or definition of the alternatives, identifying any necessary conventions. The mirrored scale at the bottom gave a spatial effect which provoked the desired sequential method of response completion: determining first if the left or right item was more important, using the associated side of the scale to record to what degree the selected item was more important.

(b) The survey instruments were printed on individual 5x7 cards and consolidated into ordered packets, held together by rings. The assembled survey provided historical evidence to the exact input of each member of the surveyed population. The instruments were identified by alphanumeric coding which precluded identification of surveyees in conjunction with their answers.

(2) Execution

(a) **Identification of Surveyees.** An operational, as well as a technical evaluation and perspective, was desired of those surveyed. Immediate efforts were made to locate both key military and civilian individuals having an integral association with the planning, selection, or utilization of the systems in contention for POM dollars. This ultimately resulted in a group of significant size spread throughout the Army.

(b) **Timeframe.** Decisionmaker surveys were conducted during the period 22 August to 8 November 1991 and consisted of scheduled 30-minute blocks of time for a short VAA overview briefing followed by the surveys. The surveys were conducted in isolated settings with only the surveyee and survey team members present. The list of surveyees, shown in Table 5-1, was later extended to include major command deputy chiefs of staff for resource management (DCSRMs), selected general officers, and senior DA civilians. (See Appendix D, Memorandum, Identification of VAA Decisionmaker Surveyees, 1 Aug 92).

Table 5-1. Surveyees

ASA(RDA)	DUSA(OR)
Deputy ASA (Plans and Programs)	Military Deputy to the ASA(RDA)
Comptroller of the Army	DCSOPS
DCSLOG	DISC4
DAS	DCSPER
DCSINT	Director, PAED
ADCSOPS (Force Development)	

(3) **Geometric Mean Pooling.** The AHP is designed to provide a single weighting value for all alternatives at every level. Normally, this is done on a single occasion, and if involving a group of individuals, it is done in a group setting with debate and discussion on each pairwise assessment. Because the Value Added

Analysis was targeted toward the HQDA level, it was immediately apparent that it would be impossible to have the entire survey population together for such a process. This led to an aggregating approach which used the geometric mean of all responses for a given pairwise comparison as a component of a composite survey. The geometric mean is the nth root of the product of the responses. The geometric mean seemed to be intuitively appealing as it tended to coincide with the "center of mass" opinion of the group and would be less affected by extreme or outlying responses as the arithmetic mean would be. As for not being done in a group environment, it was concluded that this separate but pooled technique actually enhanced the survey's validity as group and interpersonal dynamics were precluded.

(4) **Results.** The following are the results from the surveys given for VAA Phase II.

Effectiveness weights:

Implicit	0.2303
Explicit	0.7696

Implicit criteria weights:

Political risk	0.0578
Programmatics	0.0655
Asset versatility and deployability	0.2380
Operational and technical risk	0.1734
Criticality of need	0.3135
Impact on sustainability WRT combat	0.1516

Explicit criteria MOE weights:

Fractional exchange ratio	0.4653
Blue force surviving	0.5346

(5) **Sample Feedback from Surveyees.** Feedback is provided to demonstrate the depth of personal opinion which was provided by the survey participants.

- Justifying the Armed Forces is more pressing a need than justifying the Army materiel requirement of the future.

- With respect to timeframes and scenarios, I would have a much different weighting if the survey was given in the context of potential for occurrence of combat.

- Those surveyees not having DCSOPS or PAE experience should not have their answers count as much.

- I hate political elements in these (budgeting) processes and I ignore them. (Note: political risk was not the 5th or 6th ranked secondary factor for this individual.)

b. Consolidated Feedback. Because of the variety and breadth of the feedback as well as similar comments repeated among several individuals, a compendium of feedback entries is provided below.

(1) A number of surveyees provided opinions on the type of presentation that should be used to display the results of Value Added Analysis. This included showing a breakdown between program, RDTE, and sustainment costs with the program items displaying priority, quantity, and position on the program timeline. It appeared that money distribution by year and the related breakdown of system costs and force benefits was desired. This would be one of the most difficult displays of information to compose successfully.

(2) Data was commonly viewed as the cornerstone of the VAA and POM process. As such, it was suggested that the Secretary of the Army (Research, Development, and Acquisition) (SA(RDA)) be principally involved in providing salient and timely baseline program data such as minimum sustaining rates, current production rates, maximum rates, economic order quantities, and minimum programs required. This type of information would also allow some additional insight into program flexibility.

(3) VAA should establish a correlation of costs with the secondary factors.

(4) Some surveyees were concerned with fleet age (in conjunction with the optimization), especially RAM (reliability, availability, and maintainability) and associated technological implications.

(5) It was reiterated on several occasions that VAA was working on "big dollar items/programs," so the methodology must be credible.

(6) Some surveyees questioned the specific things (in order of impact) that affect RDA. In particular, does the Office of the Secretary of Defense (OSD) (an external influence) or elasticity of program have the greatest effect?

(7) Most of the fiscal orientation of VAA is on what is the best program to get for a prescribed TOA. A look at the marginal value of additional or less TOA would open an entirely new avenue of analysis.

(8) Force structure was identified as being an important variable in Value Added, most often fixed by assumption. Can VAA look into the sensitivities of varying force structure as well as program? And how are reserves considered?

(9) Current POM development is centered on mission and functional areas, each with their own proponents and offering area fixes. VAA should attempt to transcend this, not only with a macro view but a magna-view (incorporate nonwarfighting considerations) of how to do this (program building) better.

(10) Several surveyees spoke of how they felt that SWA has not yet settled down, despite growing attitudes to this effect. They said that SWA may be at the top of many people's list in the present and falls to last in the mid- and far-terms, but they believe this to be erroneous. One facet of concern is that in SWA, the enemy is not being looked at in the right light: the opposition will be much more modernized and will often look like the US equipmentwise.

(11) One individual remarked that the issue of sustainability used to irritate him when he was an officer at the tactical level, but now it has overwhelming importance in a strategic sense. He was happy to see it included within the framework of VAA.

(12) A recurring theme of fear of "hollow" forces was found in the survey population. The term "hollow" appeared to hold different implications to different individuals.

(13) One particularly interesting discussion centered on the existence of a gestation period for systems. This period is one in which money needs to be spent despite the fact that the potential and integration issues of the system are not yet realized.

(14) With the notion of leap ahead technological goals in vogue, one individual qualified the current most pressing problem as one of deciding do we live with what we have in the mid-term so that we can afford greater payoff items in the far-term, or do we buy for both mid- and far-term but on a smaller scale?

(15) Several individuals thought that certain personal characteristics were necessary in the surveyees in order to provide worthwhile information during the conduct of the surveys. There was a concern that other surveyees may not have the proper view or perspective to provide meaningful input in the POM building process. In the words of one surveyee, "You don't know what you don't know."

(16) Some held that NEA was of great importance and would continue to rise to most important over time. Especially in economic terms, the importance of the Pacific basin will change operating requirements for systems. Much of the current systems are not optimized for fighting in Asia.

(17) It was pointed out in one discussion that the warfight in SWA is the same as that of CFE, the most prominent difference being the element of navigation where SWA was more difficult. It was concluded, however, that CFE proves to be a more stressful environment. This added stress was empirically evidenced by acceptable effective exchange rates on the order of 4 or 6 to 1 in Europe but now 400-1,000 to 1 in SWA.

(18) The biggest dilemma--how to articulate need for military in light of public/Congressional opinion of a world free of threats and defining the forces needed to accomplish this new mission.

(19) This (the POM building process) is a political decision in the long run.

(20) Modernization is more important as the force gets smaller.

(21) 1974 was a watershed year in the way things were looked at in the Army. The seeds of the Gulf War were sown in this timeframe because a more holistic look was taken. What the Army must have now is a larger perspective--a world view (useful everywhere).

(22) Suggestions were offered regarding measures of effectiveness: quickness, decisiveness, and minimum casualties.

(23) Lethality and mobility have increasing importance as a function of time and should have increasing weight accordingly.

(24) There is a corps-level orientation (not division).

(25) Capital investment strategy should be a leap ahead if there is not a compelling threat.

(26) Requirements should be first (referring to the requirement-based acquisition priority).

(27) The US may be faced with a Third World power who has bought British, German, or other Western equipment. Therefore, very high tech armies may be faced.

(28) Stability of RDTE and RDA as a whole are especially important.

(29) Look at operating and support (O&S) costs when procurement commitments are made. Tradeoff between savings achieved by new systems not obtained because old systems had to be kept. Need to trade off between force structure and equipment. Eliminate high-low mixes of modernized systems. All units should be equipped the same.

(30) Political risk could be overriding. Could this be a supervalue criterion?

(31) At least one surveyee thought the higher the rank of the survey population, the better the quality of the answers, but he agreed that the anonymity of the survey process lent itself well to increasing the value of any of the surveys.

(32) The six secondary factors equate to Mr. Convers' four characteristics of a viable system: (1) validated need, (2) approvable (in Pentagon and Congress perspective), (3) program executable, and (4) affordable (cost).

(33) In discussing alternatives to LER/FER: how fast are objectives achieved, total combat time, and total force applied defined as area versus time?

(34) One significant problem concerns the long time used to develop systems. Even though the US thinks near-term, there is no long-range development thinking.

(35) There is no need for a 2008 timeframe in VAA as there are too many things which are undefined and extrapolated (e.g., threat).

(36) In terms of scenario, a concurrent contingency scenario is needed (any one contingency scenario does not stress our capabilities).

c. Decisionmaker Survey Assessment. Across the board, these participants were knowledgeable and demonstratively capable individuals. If the quality of the results is characterized by the quality of the participation of the survey population and the veritable wealth of insight proffered, then it can be said that the quality was superb.

5-10. SUBJECT MATTER EXPERT (SME) SURVEY

a. **Development.** The SME survey was designed to provide the assessments (values) of the alternatives in terms of their respective success in fulfilling the most favorable aspects of the six secondary factors previously defined. Originally, this was envisioned to be a pairwise comparison activity similar to the decisionmaker survey but, owing to the number of alternatives and the resulting quantity of questions, it was felt that SME effort would be overwhelming and unrealistic. The survey finally completed consisted of a scoring of each of the systems in terms of the secondary factors.

b. **Execution.** A survey package was compiled which included an instructional memorandum, read-ahead memo, long and short system title and definitions, and survey. The system title and definitions, in addition to serving as a convention for nomenclature, were used as an input device to allow the surveyees to provide additional comments on the actual or current composition of the program.

(1) The survey population was identified as being the various offices of the DCSOPS. Each of the individual offices was tasked with the responsibility of staffing and completing respective elements (programs applicable) of their surveys. This staffing was to include appropriate communications with project managers, system managers, applicable organizations of the Secretariat, and other Headquarters, Department of the Army level organizations having knowledge of the programs. The ultimate goal was to provide a multilateral assessment at the "expert" level of the current state of the program within the contexts of the six secondary factors.

(2) A example portion of the SME survey package is displayed in Figure 5-3.

SUBJECT MATTER EXPERT SURVEY INSTRUCTIONS
Consider each of the following systems under the secondary factor given. Determine to what extent the system embodies the most positive aspects of the factor. Indicate your evaluation by making an X in the appropriate square on the scale to the right of the system name. Note that the scale value increases (to the right) with desirability.

SECONDARY FACTOR: Political Risk

The subjective evaluation of the supportive or non-supportive attitude prevalent across the scope of public, congressional, executive, and Army interest groups regarding the proposed program. Greater political risk is, by convention, less desirable.

	EXTREME RISK	MODERATE RISK	LOW RISK
1 HET	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]
2 SADARM MLRS	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]
3 TOW 2A/2B	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]
4 AAWS-M	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]
5 ADATS	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]
6 AEI	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]
7 AFAS	[1] [2] [3]	[4] [5] [6]	[7] [8] [9]

Figure 5-3. Example - Survey Instructions

c. **Results.** The final scores for the systems as they relate in each of the secondary factors are given in Table 5-2. Note that the convention is the larger the number, the more favorable the evaluation.

Table 5-2. Secondary Factors Survey Results

	Political risk	Programmatics	Asset versatility & deployability	Operational and technological risk	Criticality of need	Impact on sustainability (cbt)
HET	7	7	7	8	5	7
MLRS SADARM	5	4	7	4	6	6
TOW 2A/2B	9	8	8	7	5	6
AAWS-M	5	3	8	4	8	6
ADATS	3	3	6	6	8	6
AFAS	6	3	7	4	6	4
AGS	4	3	8	6	7	4
AH-64 LB	6	4	8	6	6	7
AMS-H	5	5	6	5	5	5
ATAS	5	6	8	6	5	4
AVENGER	8	8	9	7	5	6
Adv QUICKFIX	6	6	8	5	5	5
BLOCK III	4	2	6	4	7	6
CMV	6	3	6	6	7	6
FIFV	4	2	6	4	5	4
JSTARS	6	5	9	6	8	8
RAH-66LB	5	3	8	5	7	7
RAH-66	6	5	8	6	8	7
LOSAT	5	3	6	6	8	7
155 LtWt	5	5	8	6	4	5
M1A2	3	3	6	6	4	5
MLRS TGW	3	2	6	4	6	6
NLOS-AT	3	3	6	5	7	6
WAM	6	5	7	6	5	6
155 ER	4	4	8	6	4	5
155 TGP	4	3	8	5	4	5
ARV	5	4	6	7	4	6
Adv SEMA	4	5	8	6	6	6
Advanced Firefinder	6	6	8	7	6	7
VOL Air	6	5	7	7	5	5
FARV-A	5	4	7	8	5	6
FMTV 2.5	5	7	9	9	6	7
FMTV 5	6	7	8	9	7	7
GBCS-L/H	5	5	7	7	6	6
GBS	5	5	7	7	6	6
HAB	6	5	6	8	6	6
PLS	6	7	8	8	7	7
STINGRAY	5	5	7	6	8	6
VEMASID	7	6	6	6	7	6
VOL Gnd	7	7	7	7	6	5
ATACMS II	7	4	7	5	7	7

5-11. FUTURE DEVELOPMENTS. A number of lessons were learned during the evolution of the surveys which lend themselves to changes to the process in order to improve it.

a. The mechanics of the survey process revealed an automated survey could be envisioned as substantially more beneficial as compared to the current paper process. The primary benefits would include sequential breakdown of the pairwise comparison elements, error checking during execution, feedback of survey results upon completion, and less human intervention in the manipulation of the final survey data. One possibility is the development of an artificial intelligence/expert system module designed to assist the surveyee in the maintenance of consistency or recording the specific rationale for the inconsistencies.

b. The subject matter expert survey design was a departure from the pairwise comparison approach because the number of comparisons would be significant, and the scope of subject matter expertise is often very confined. A procedure in which a large number of SME participants could provide independent and narrow scope assessments has been devised. Currently referred to as the shingles approach, such a mechanism would access a much larger space of expertise with a reasonable quantity of comparisons.

c. One particular strategy of analysis which was not conducted was the breakdown of the assessments by aggregating inputs categorically. Some categories of possible interest would be branch affiliation, flag versus field grade versus civilian, category of current position (e.g., logistic), major Army command (MACOM) versus ARSTAF, and recent (post-Vietnam) combat experience versus no combat experience.

d. A final possible development is an assessment mechanism of individual, often subconscious, tendencies associated with the taking of the survey. For example, it was noted by the team that some surveyees seemed to habitually favor the left alternative in a given series of analyses despite the generation of inconsistencies. In another aspect, it was noted that some surveyees were extreme in their assessments, predominantly choosing the absolute or near absolute evaluation of importance while others were neutral. Such an analysis, especially in conjunction with the expert system environment, could provide an adaptive survey instrument designed to minimize the effect of such tendencies.

5-12. CONCLUSIONS

a. The survey process proved to be an impressive mechanism for the acquisition of weighting factors. It was modular, adaptable, insightful, thought-provoking, and realistic. The use of the analytic hierarchy process with its pairwise comparison technique provided substance to the attempt to capture, quantitatively, those aspects of the program development process which commonly defy expression in numerical terms. In the course of gathering such information, the Value Added team, as well as the survey participants, gained additional insights into how various components of the process related to one another. This, in and of itself, was a significant contribution of the surveys. Combine this insight with the weightings themselves, and the resulting compilation of information is a demonstrably viable and useful analytic product.

b. The success of the reception of the results by the survey population also supports the contention that the survey was a viable medium for the development of weighting values as well an introspective look into the mindset of the survey population.

CHAPTER 6

EFFECTIVENESS INTEGRATION

6-1. PURPOSE AND USE. This chapter discusses the Effectiveness Integration Module of the Value Added Analysis. Figure 6-1 shows how the Effectiveness Integration Module is related to other VAA modules.

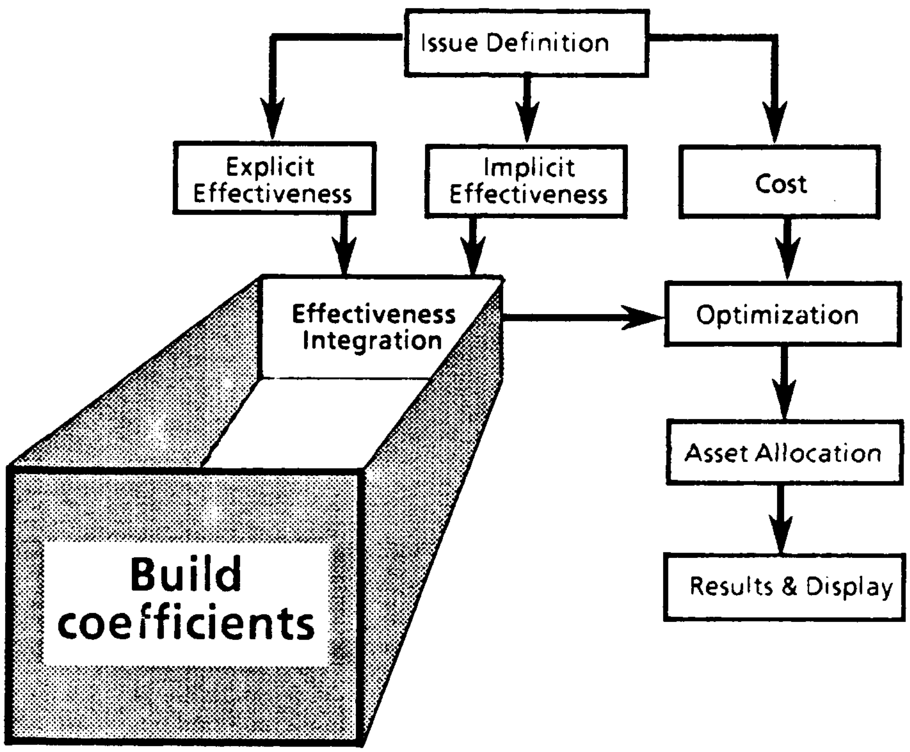


Figure 6-1. Value Added Analysis Effectiveness Integration Module

a. Purpose. The Effectiveness Integration Module provides an organized framework to integrate multiple factors that measure a weapon system's value into one overall effectiveness coefficient. An effectiveness coefficient is computed for each VAA system; collectively, they provide a relative ranking of the value of VAA systems.

b. Use. Effectiveness coefficients from the Effectiveness Integration Module are used by the Optimization Module in its cost-benefit tradeoffs to determine the subset of VAA systems that provides maximum effectiveness for constrained resources. TOPSIS is the analytical tool within the Effectiveness Integration Module that computes the effectiveness coefficients.

6-2. ANALYTICAL MODELS AND TOOLS - TOPSIS. VAA supports the ARSTAF with a quick turnaround capability to perform cost-benefit analysis of competing alternative systems during the development of the Army POM. A subtask of this support is ranking all alternative systems in terms of their relative value. All competing systems must be consistently judged against several, possibly conflicting, criteria. An analytical tool is required to do the ranking due to the potentially large numbers of alternative systems, multiple decision criteria, and potential bias of decisionmakers. Multiple attribute decisionmaking (MADM) tools are well-suited to this kind of problem. MADM tools assist the decisionmaker in making logical and consistent rankings of alternatives. TOPSIS, a MADM tool, was used for effectiveness integration in both Phases I and II of VAA. Several alternatives to TOPSIS were evaluated during Phase I and are documented in Chapter 8 of the Phase I Report. TOPSIS was selected based on its popularity within the Army community, its ease of use, its simplicity, and its clear ranking of alternatives.

a. TOPSIS Overview. TOPSIS was developed by Chaing-Lai Hwang and Kwangusn Yoon. It can be used to compare many alternatives that have many common attributes or criteria, regardless of the attribute's units of measure. The basic TOPSIS problem is illustrated in Figure 6-2, where matrix rows represent alternatives (A_i), columns represent criteria (C_i), and the weight associated with each criteria is represented as W_i. TOPSIS is based on the concept that preference should be given to the alternative that is both the shortest distance from the "ideal" solution (best alternative) and the farthest distance from the "negative-ideal" solution (worst alternative). Figure 6-3 illustrates the concept using two alternatives A_1 and A_2. Notice that alternative A_1 has shorter distances (both to the ideal solution A^* and to the negative-ideal solution A^-) than alternative A_2. Therefore, it is difficult to justify selection of A_1 over A_2 based on the Euclidian distances alone. TOPSIS considers the distances to both the ideal and negative-ideal solution simultaneously by taking the relative closeness to the ideal solution.

- Given:

  Criteria weights

$$W_1 \quad W_2 \quad \cdots \quad W_m$$

  Raw score decision matrix

$$
\begin{array}{c c}
 & \begin{array}{cccc} C1 & C2 & \cdots & C_m \end{array} \\
\begin{array}{c} \text{Alt 1} \\ \text{Alt 2} \\ \vdots \\ \text{Alt n} \end{array} &
\begin{pmatrix}
X_{21} & X_{22} & \cdots & X_{2,m} \\
X_{11} & X_{12} & \cdots & X_{1,m} \\
 & & \vdots & \\
X_{n,1} & X_{n,2} & \cdots & X_{n,m}
\end{pmatrix}
\end{array}
$$

Figure 6-2. Example Matrix for Basic TOPSIS

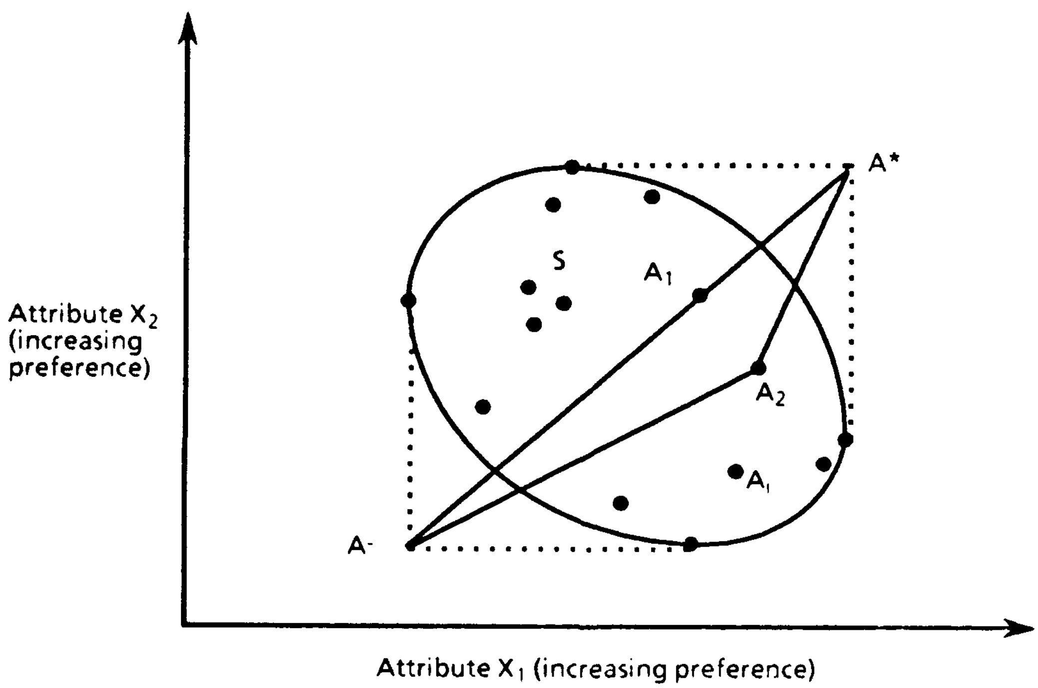


Figure 6-3. Euclidean Distances to the Ideal and Negative-ideal Solution in Two-dimensional Space

b. TOPSIS Algorithm. For ease of presentation, the TOPSIS method can be presented as a series of operations on a matrix with different alternatives (rows) and decision criteria used to judge the alternatives (columns). The elements of the matrix represent the contribution of each alternative to achieving the criteria. The parameters of the Phase II decision matrix include 41 alternative systems (rows) and eight decision criteria associated with three time periods and three theaters (8 x 3 x 3 = 72 columns).

(1) Inputs to TOPSIS. There are two basic types of inputs to TOPSIS--the scores, which are elements of the decision matrix, and the criteria weights, since all criteria are normally not valued equally by decisionmakers.

(a) Scores. The scores in the decision matrix are the values for each alternative system's contribution to each of the criteria. All VAA systems are not available in every theater and every time period. For example, of the 41 VAA systems, only 20 are available in the near-term (1996), 33 are available by mid-term (2001), and all 41 are available long-term (2008). Table 6-1 depicts the decision matrix scores for the 20 near-term systems over eight decision criteria for the Contingency Scenario in 1996. Decision matrices similar to Table 6-1 were developed for each theater and time period. The scores represent the value of both explicit and implicit factors.

Table 6-1. Decision Matrix Scores for Contingency 96

Criteria	Contingency Scenario 96							
	FER	BFS	Political risk	Programmatics	Asset V&D	O&T risk	Crit of need	Sustainability
AAWS-M	.2750683	.0229967	5	3	8	4	8	6
ADATS	.2633635	.0167408	3	3	6	6	8	6
ADV QUICKFIX	.2001821	.0221318	6	6	8	5	5	5
ARV	-.002206	-.002277	5	4	6	7	4	6
ATAS	.1703440	.0113128	5	6	8	6	5	4
AVENGER[a]	0	0	0	0	0	0	0	0
FMTV5	-.148385	-.009207	6	7	8	9	7	7
GBCS-L/H	.0675732	.0041592	5	5	7	7	6	6
HAB	[illegible]	.0057106	6	5	6	8	6	6
HET	-.037204	.0022422	7	7	7	8	5	7
JSTARS	.1925984	.0137656	6	5	9	6	8	8
M1A2	-.058277	.0004247	3	3	6	6	4	5
SADARM	.1195902	.0106882	5	4	7	4	6	6
PLS	.066619	.01113	6	7	8	8	7	7
TOW2B	-.030435	-.000732	9	8	8	7	5	6
VEMASID	-.062723	.000896	7	6	6	6	7	[illegible]
AIR VOLCANO	.2073552	.009423	6	5	7	7	5	5
VOLCANO	-.105956	.002345	7	7	7	7	6	5
WAM	.4957914	.0357311	6	5	7	6	5	6
FMTV2.5	-.148385	-.009207	6	7	8	9	7	7

[a]Base case system for Contingency Scenario

1. Explicit Scores. Scores for the explicit factors (fractional exchange ratio and Blue force surviving) are derived from theater and time period dependent combat simulations as discussed in Chapter 4.

2. Implicit Scores. Recall from Chapter 5 that the six implicit factors are (1) Political Risk, (2) Programmatics, (3) Asset Versatility and Deployability, (4) Operational and Technological Risk, (5) Criticality of Need, and (6) Impact on Sustainability with respect to combat. The score for each alternative against the implicit factors is provided by the Subject Matter Expert (SME) Survey. Refer to Chapter 5 for definitions of implicit factors and details on the SME Survey. Scores of a system against implicit factors are not theater or time period dependent, provided the system is available in the theater during the period. For example, the AAWS-M is available to all theaters and years; therefore, its implicit scores are the same for all theater and time periods. AVENGER, on the other hand, is not a candidate system in the Contingency Scenario in 1996 because it is already fielded. Therefore, it receives no value in this scenario.

(b) Criteria Weights. VAA criteria weights represent the relative importance that Army decisionmakers assign to the various decision criteria. The criteria weights for VAA Phase II are summarized in Table 6-2. The criteria weighting survey of Army senior leaders provided the data used to compute criteria weights. Chapter 5 discusses the criteria weighting survey and the procedure (AHP) that was used to compute the weights.

Table 6-2. Summary of VAA Criteria Weights

Scenario weights by theater and year:				
	Year	**Contingency**	**Stressful**	**NEA**
	1996	0.1564	0.0522	0.1462
	2001	0.1825	0.1037	0.1055
	2008	0.1082	0.0882	0.0567
Effectiveness weights:				
	Implicit			0.2303
	Explicit			0.7696
Implicit criteria weights:				
	Political risk			0.0578
	Programmatics			0.0655
	Asset versatility and deployability			0.2380
	Operational and technical risk			0.1734
	Criticality of need			0.3135
	Impact on sustainability WRT combat			0.1516
Explicit criteria MOE weights:				
	Fractional exchange ratio			0.4653
	Blue force surviving			0.5346

(2) **TOPSIS Procedures.** The steps in the TOPSIS algorithm are summarized below, in Figure 6-4, along with the mathematics for each step. The TOPSIS steps are sequential operations that begin with the initial decision matrix. The matrix is first normalized to allow for comparison across criteria or columns. Since all attributes may not have equal importance or weight, the next step is to construct the weighted normalized decision matrix. The third step is to determine ideal and negative-ideal solutions by choosing the best available weighted normalized score for each criteria and the worst available weighted normalized score for each criteria. In step 4, the distance from each alternative to both the ideal and negative-ideal is calculated. This step assumes that the distance from the negative-ideal is just as important to the decisionmaker as the distance to the ideal. Step 5 calculates the relative closeness to the ideal solution or the TOPSIS score, and finally the preference order is determined.

- Step 1: Normalize Decision Matrix

r_{ij} = normalized element of decision matrix

$$= \frac{X_{ij}}{\left(\sum_{i=1}^{n} X_{ij}^{2} \right)^{1/2}} \quad \forall i,j$$

- Step 2: Weight Normalized Decision Matrix

$$v_{ij} = w_j r_{ij},\ i = 1,\ldots, n \text{ and } j = 1,\ldots, m$$

- Step 3: Find Ideal and Negative-Ideal Vectors

$$A^{*} = \{ \max_{i} V_{ij} \mid i = 1,\ldots,n \} = (V_{1,}^{*}\ V_{2,}^{*} \ldots, V_{m}^{*})$$

$$A^{-} = \{ \max_{i} V_{ij} \mid i = 1,\ldots,n \} = (V_{1,}^{-}\ V_{2,}^{-} \ldots, V_{m}^{-})$$

- Step 4: Calculate Separation Measures

$$S_{i}^{*} = \left(\sum_{j-1}^{m} (V_{ij} - V_{j}^{*})^{2} \right)^{1/2}, \forall i$$

$$S_{i}^{-} = \left(\sum_{j-1}^{m} (V_{ij} - V_{j}^{-})^{2} \right)^{1/2}, \forall i$$

- Step 5: Calculate TOPSIS Score

$$C_{i} = \frac{S_{i}^{-}}{S_{i}^{*} + S_{i}^{-}}, \forall i$$

Figure 6-4. Steps of Basic TOPSIS

(3) TOPSIS Output. The above procedure yields TOPSIS scores (coefficients) which fall between zero (0.0) and one (1.0) for each system. The largest TOPSIS coefficient indicates the preferred alternatives. TOPSIS results are presented in paragraph 6-3.

c. TOPSIS Implementation. Implementation continued to be one of the primary considerations in selecting TOPSIS for Phase II just as it had been in Phase I. After the completion of Phase I, the United States Military Academy (USMA) conducted an analysis of the mathematical foundations of TOPSIS. Based on the USMA analysis and lessons learned by the Phase I study team, several changes were recommended to Phase I TOPSIS which were implemented as a C-Language program on a PC.

(1) **Phase II Implementation.** In order to provide timely Phase II support to building the FY 94 - FY 99 POM, Phase II TOPSIS was implemented as spreadsheets. Spreadsheet implementation was considered more timely than modifying the C-Language program to evaluate recommended changes to Phase I TOPSIS which included:

(a) Use fixed upper and lower bounds when establishing the ideal and negative-ideal to preclude rank order changes (USMA suggestion).

(b) Avoid washing out implicit factors.

1. Compute TOPSIS results for explicit and implicit factors separately and then combine them using their respective weights.

2. Do not normalize the implicit factors which represent a common unit of measure.

(2) **Implementation Environment.** Phase II TOPSIS was initially implemented on the personal computer and subsequently on the METAPHOR data base computer as contract support became available.

(a) **PC TOPSIS.** PC TOPSIS is implemented as multiple linked spreadsheets using WINDOWS 3.0 EXCEL software and IBM PC compatible hardware. Spreadsheets are good for analyzing the effect of changes in input data, provided that the operational and logical procedures remain fairly stable. Liberal use of macros ensures responsiveness of PC TOPSIS. However, a limitation is that the spreadsheets may become large and unwieldy.

(b) **METAPHOR TOPSIS.** TOPSIS was implemented on the METAPHOR data base computer which is located in the Pentagon with terminal links at CAA. Steps were taken to ensure that METAPHOR TOPSIS uses the appropriate logic and produces the expected results. Documentation of METAPHOR TOPSIS, a module of the VAA METAPHOR Desktop, will be covered in a separate document.

6-3. RESULTS. This paragraph presents some major assumptions governing computation of TOPSIS coefficients, presents the computed TOPSIS coefficients, and discusses limitation on the use of the coefficients.

a. Assumptions

(1) An alternative system receives no implicit value if it is not available to the theater in the specified time period.

(2) Decisionmakers are risk-neutral and consider the distance from the worst alternative to be just as important as the distance to the best alternative in ranking the alternatives.

b. Computed VAA Coefficients. Relative overall measures of worth, normally referred to as VAA coefficients, were computed for each alternative system by theater as well as across theaters to obtain a global view. Within a theater or multitheater scenario, separate views of the coefficients were maintained by year and by type of factors, i.e., based on implicit factors only, explicit factors only, or a combined view of implicit and explicit factors. The coefficients for the Contingency Scenario are presented in Tables 6-3, 6-4, and 6-5. Tables 6-6, 6-7, and 6-8 present similar results for the Stressful Scenario. The results for the global or multitheater view (Contingency and Stressful combined) are shown in Tables 6-9, 6-10, and 6-11.

Table 6-3. VAA System Coefficients for Contingency Scenario (implicit only)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
FMTV5	.759	FMTV5	.764	FMTV5	.765
FMTV2.5	.759	FMTV2.5	.764	FMTV2.5	.765
JSTARS	.741	PLS	.740	PLS	.740
PLS	.737	JSTARS	.729	JSTARS	.724
AAWS-M	.584	RAH 66	.695	RAH--66	.690
ADATS	.579	STINGRAY	.632	STINGRAY	.628
VEMASID	.547	LOSAT	.597	LOSAT	.592
HAB	.497	ADV FF	.576	ADV FF	.577
GND VOLCANO	.490	ADATS	.568	ADATS	.563
GBCS-L/H	.490	AAWS-M	.567	AAWS-M	.561
HET	.471	ATACMS II	.548	RAH-66-LB	.550
TOW2B	.463	VEMASID	.547	VEMASID	.546
MRS SADARM	.384	AGS	.514	ATACMS II	.544
AIR VOLCANO	.356	AH-64 LB	.514	AH-64 LB	.512
WAM	.341	HAB	.507	AGS	.510
ATAS	.338	GND VOLCANO	.504	CMV	.510
ADV QUICKFIX	.331	GBCS-L/H	.495	HAB	.509
ARV	.278	GBS	.495	GND VOLCANO	.506
M1A2	.177	HET	.490	GBCS-L/H	.496
		TOW 2B	.484	GBS	.496
		NLOS-AT	.466	HET	.495
		MLRS SADARM	.379	TOW2B	.489
		AIR VOLCANO	.372	ADV SEMA	.482
		ATAS	.353	NLOS-AT	.461
		WAM	.353	BLOCK III	.433
		ADV QUICKFIX	.344	FARV-A	.429
		MLRS TGW	.333	MLRS SADARM	.376
		155 LT WT	.292	AIR VOLCANO	.375
		ARV	.292	ATAS	.356
		155 ER	.276	WAM	.355
		AMS-H	.249	ADV QUICKFIX	.346
		155 TGP	.230	AFAS	.334
		M1A2	.187	MLRS TGW	.330
				ARV	.296
				155 LT WT	.295
				155 ER	.278
				AMS-H	.251
				155 TGP	.231
				M1A2	.189
				FIFV	.161
				AVENGER	0

Table 6-4. VAA System Coefficients for Contingency Scenario (explicit only)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
WAM	1	ADATS	1	RAH-66 LB	1
AAWS-M	.689	MLRS TGW	.791	RAH-66	.939
ADV QUICKFIX	.624	M1A2	.635	MLRS TGW	.799
ADATS	.605	AH-64 LB	.537	FIFV	.780
JSTARS	.519	HAB	.524	ADATS	.691
AIR VOLCANO	.477	WAM	.513	GBCS-L/H	.639
ATAS	.474	GBS	.497	AH-64 LB	.625
MLRS SADARM	.431	ATAS	.481	AFAS	.591
PLS	.400	RAH-66	.455	FMTV5	.589
HAB	.400	ATACMS II	.394	FMTV2.5	.589
GBCS-L/H	.315	155 TGP	.385	AIR VOLCANO	.565
HET	.220	155 LT WT	.363	155 TGP	.535
ARV	.190	ARV	.322	HET	.519
TOW2B	.186	HET	.316	ADV QUICKFIX	.503
M1A2	.184	ADV FF	.315	FARV-A	.448
VEMASID	.163	AAWS-M	.256	STINGRAY	.427
GND VOLCANO	.120	155 ER	.251	WAM	.425
FMTV 5	0	STINGRAY	.246	TOW2B	.425
FMTV 2.5	0	JSTARS	.244	HAB	.420
		FMTV5	.242	155 LT WT	.409
		FMTV2.5	.242	MLRS SADARM	.398
		GND VOLCANO	.239	VEMASID	.364
		GBCS-L/H	.231	155 ER	.349
		NLOS-AT	.219	JSTARS	.344
		AIR VOLCANO	.212	GBS	.343
		VEMASID	.211	GND VOLCANO	.313
		TOW2B	.206	ADV FF	.290
		PLS	.203	ATAS	.289
		LOSAT	.201	AAWS-M	.285
		AMS-H	.183	PLS	.280
		ADV QUICKFIX	.174	ADV SEMA	.261
		MLRS SADARM	.162	AMS-H	.257
				NLOS-AT	.255
				LOSAT	.217
				ATACMS II	.214
				ARV	.191
				CMV	.167
				AGS	.167
				BLOCK III	.138
				M1A2	0
				AVENGER	0

Table 6-5. VAA System Coefficients for Contingency Scenario (combined implicit and explicit)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
WAM	976	ADATS	.984	RAH-66 LB	.985
AAWS-M	.669	MLRS TGW	.790	RAH-66	.938
ADV QUICKFIX	.623	M1A2	.635	MLRS TGW	.798
ADATS	.605	AH-64 LB	.537	FIFV	.779
JSTARS	.520	HAB	.524	ADATS	.691
AIR VOLCANO	.477	WAM	.513	GBCS-L/H	.639
ATAS	.474	GBS	.497	AH-64 LB	.625
MLRS SADARM	.431	ATAS	.481	AFAS	.591
PLS	.401	RAH-66	.456	FMTV5	.589
HAB	.400	ATACMS II	.394	FMTV2.5	.589
GBCS-L/H	315	155 TGP	.385	AIR VOLCANO	.565
HET	.221	155 LT WT	.363	155 TGP	.535
ARV	.190	ARV	.322	HET	.519
TOW2B	.187	HET	.317	ADV QUICKFIX	.503
M1A2	.184	ADV FF	.315	FARV-A	.448
VEMASID	.164	AAWS-M	.257	STINGRAY	.427
GND VOLCANO	.122	155 ER	.251	WAM	.425
FMTV5	.028	STINGRAY	.247	TOW2B	.425
FMTV2.5	.028	JSTARS	.245	HAB	.420
		FMTV5	.243	155 LT WT	.409
		FMTV2.5	.243	MLRS SADARM	.398
		GND VOLCANO	.240	VEMASID	.364
		GBCS-L/H	.231	155 ER	.349
		NLOS-AT	.220	JSTARS	.345
		AIR VOLCANO	.212	GBS	.343
		VEMASID	.211	GND VOLCANO	.314
		TOW2B	.206	ADV FF	.291
		PLS	.203	ATAS	.289
		LOSAT	.202	AAWS-M	.286
		AMS-H	.183	PLS	.281
		ADV QUICKFIX	.174	ADV SEMA	.261
		MLRS SADARM	162	AMS H	.257
		AGS	.017	NLOS-AT	.256
				LOSAT	.218
				ATACMS II	.215
				ARV	.191
				CMV	.168
				AGS	.168
				BLOCK III	139
				M1A2	.007
				AVENGER	0

Table 6-6. VAA System Coefficients for Stressful Scenario (implicit only)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
FMTV5	.760	FMTV5	.764	FMTV5	.765
FMTV2.5	.760	FMTV2.5	.764	FMTV2.5	.765
JSTARS	.743	PLS	.741	PLS	.741
PLS	.738	JSTARS	.731	JSTARS	.727
AAWS-M	.587	RAH-66	.698	RAH-66	.693
ADATS	.583	STINGRAY	.636	STINGRAY	.631
VEMASID	.549	LOSAT	.601	LOSAT	.596
HAB	.499	ADV FF	.575	ADV FF	.576
GBCS-L/H	.490	ADATS	.573	ADATS	.567
GND VOLCANO	.490	AAWS-M	.572	AAWS-M	.565
AVENGER	.486	ATACMS II	.550	RAH-66 LB	.553
HET	.469	VEMASID	.549	VEMASID	.547
TOW2B	.460	AH-64 LB	.514	ATACMS II	.546
MLRS SADARM	.386	HAB	.507	CMV	.513
AIR VOLCANO	.354	GND VOLCANO	.503	AH-64 LB	.512
WAM	.339	AVENGER	.502	HAB	.508
ATAS	.336	GBCS-L/H	.496	AVENGER	.507
ADV QUICKFIX	.328	GBS	.496	GND VOLCANO	.505
ARV	.277	HET	.486	GBCS-L/H	.496
M1A2	.177	TOW2B	.479	GBS	.496
		NLOS-AT	.470	HET	.492
		MLRS SADARM	.381	TOW2B	.485
		AIR VOLCANO	.370	ADV SEMA	.483
		ATAS	.351	NLOS-AT	.465
		WAM	.351	BLOCK III	.437
		ADV QUICKFIX	.341	FARV-A	.427
		MLRS TGW	.336	MLRS SADARM	.378
		ARV	.290	AIR VOLCANO	.373
		155 LT WT	.290	ATAS	.354
		155 ER	.274	WAM	.353
		AMS-H	.248	ADV QUICKFIX	.344
		155 TGP	.229	AFAS	.336
		M1A2	.186	MLRS TGW	.332
				ARV	.294
				155 LT WT	.293
				155 ER	.276
				AMS-H	.249
				155 TGP	.230
				M1A2	.188
				FIFV	.163

Table 6-7. VAA System Coefficients for Stressful Scenario (explicit only)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
AAWS-M	.624	RAH-66	.731	FIFV	1
HAB	.609	GBS	.590	AH-64 LB	.548
WAM	.594	HAB	.561	BLOCK III	.465
TOW2B	.530	M1A2	.557	RAH-66 LB	.463
VEMASID	.520	ADV FF	.554	AAWS-M	.444
M1A2	.508	NLOS-AT	.521	RAH-66	.429
GND VOLCANO	.471	155 ER	.514	GBS	.429
FMTV5	.467	AH-64 LB	.497	TOW2B	.410
FMTV2.5	.467	WAM	.481	M1A2	.409
ARV	.466	AMS-H	.457	HAB	.385
AIR VOLCANO	.464	GBCS-L/H	.453	PLS	.381
HET	.439	JSTARS	.418	WAM	.352
ADATS	.430	ARV	.399	JSTARS	.351
PLS	.348	AVENGER	.388	ADATS	.313
ATAS	.330	MLRS SADARM	.344	ATACMS II	.310
JSTARS	.322	PLS	.341	VEMASID	.287
ADV QUICKFIX	.321	TOW2B	.340	155 LT WT	.287
AVENGER	.265	ADV QUICKFIX	.337	AMS-H	.283
MLRS SADARM	.171	HET	.310	STINGRAY	.281
GBCS-L/H	.019	ATAS	.292	AVENGER	.280
		ADATS	.283	155 ER	.280
		LOSAT	.277	AFAS	.263
		AAWS-M	.277	ADV FF	.256
		MLRS TGW	.273	MLRS TGW	.232
		GND VOLCANO	.269	AIR VOLCANO	.231
		STINGRAY	.238	ARV	.229
		ATACMS II	.203	FARV-A	.227
		155 LT WT	.182	ADV SEMA	.210
		AIR VOLCANO	.165	HET	.209
		FMTV5	.117	GBCS-L/H	.207
		FMTV2.5	.117	FMTV5	.173
		VEMASID	.103	FMTV2.5	.173
		155 TGP	.089	NLOS-AT	.164
				GND VOLCANO	.152
				LOSAT	.123
				CMV	.116
				ATAS	.113
				155 TGP	.095
				MLRS SADARM	.094
				ADV QUICKFIX	.068

Table 6-8. VAA System Coefficients for Stressful Scenario (combined implicit and explicit)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
AAWS-M	.624	RAH-66	.731	FIFV	.979
HAB	.609	GBS	.589	AH-64 LB	.547
WAM	.594	HAB	.561	BLOCK III	.465
TOW2B	.530	M1A2	.557	RAH-66 LB	.463
VEMASID	.520	ADV FF	.554	AAWS-M	.444
M1A2	.508	NLOS-AT	.521	RAH-66	.429
GND VOLCANO	.471	155 ER	.514	GBS	.429
FMTV5	.467	AH-64 LB	.497	TOW2B	.410
FMTV2.5	.467	WAM	.481	M1A2	.409
ARV	.466	AMS-H	.456	HAB	.385
AIR VOLCANO	.464	GBCS-L/H	.453	PLS	.381
HET	.437	JSTARS	.418	WAM	.352
ADATS	.428	ARV	.399	JSTARS	.352
PLS	.349	AVENGER	.388	ADATS	.313
ATAS	.330	MLRS SADARM	.344	ATACMS II	.310
JSTARS	.323	PLS	.341	VEMASID	.288
ADV QUICKFIX	.321	TOW2B	.340	155 LT WT	.287
AVENGER	.266	ADV QUICKFIX	.337	AMS-H	.283
MLRS SADARM	.172	HET	.310	STINGRAY	.281
GBCS-L/H	.024	ATAS	.292	AVENGER	.280
		ADATS	.283	155 ER	.280
		LOSAT	.278	AFAS	.263
		AAWS-M	.277	ADV FF	.256
		MLRS TGW	.273	MLRS TGW	.232
		GND VOLCANO	.270	AIR VOLCANO	.231
		STINGRAY	.239	ARV	.229
		ATACMS II	.203	FARV-A	.228
		155 LT WT	.182	ADV SEMA	.210
		AIR VOLCANO	.165	HET	.209
		FMTV5	.119	GBCS-L/H	.207
		FMTV2.5	.119	FMTV5	.174
		VEMASID	.104	FMTV2.5	.174
		155 TGP	.090	NLOS-AT	.165
				GND VOLCANO	.153
				LOSAT	.125
				CMV	.117
				ATAS	.113
				155 TGP	.095
				MLRS SADARM	.094
				ADV QUICKFIX	.068

Table 6-9. VAA System Coefficients for Contingency and Stressful Scenarios (combined implicit)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
FMTV5	.759	FMTV5	.764	FMTV5	.765
FMTV2.5	.759	FMTV2.5	.764	FMTV2.5	.765
JSTARS	.741	PLS	.740	PLS	.741
PLS	.737	JSTARS	.729	JSTARS	.725
AAWS-M	.584	RAH-66	.696	RAH-66	.692
ADATS	.579	STINGRAY	.633	STINGRAY	.630
VEMASID	.547	LOSAT	.598	LOSAT	.594
HAB	.498	ADV FF	.576	ADV FF	.577
GND VOLCANO	.490	ADATS	.569	ADATS	.565
GBCS-L/H	.490	AAWS-M	.568	AAWS-M	.563
AVENGER	.486	ATACMS II	.548	RAH-66 LB	.551
HET	.471	VEMASID	.548	VEMASID	.546
TOW2B	.463	AGS	.514	ATACMS II	.544
MLRS SADARM	.384	AH-64 LB	.514	AH-64 LB	.512
AIR VOLCANO	.355	HAB	.507	CMV	.511
WAM	.340	GND VOLCANO	.504	AGS	.510
ATAS	.338	AVENGER	.502	HAB	.508
ADV QUICKFIX	.330	GBCS-L/H	.496	AVENGER	.507
ARV	.278	GBS	.496	GND VOLCANO	.506
M1A2	.177	HET	.489	GBCS-L/H	.496
		TOW2B	.483	GBS	.496
		NLOS-AT	.467	HET	.494
		MLRS SADARM	.380	TOW2B	.487
		AIR VOLCANO	.371	ADV SEMA	.483
		ATAS	.353	NLOS-AT	.463
		WAM	.352	BLOCK III	.435
		ADV QUICKFIX	.343	FARV-A	.427
		MLRS TGW	.334	MLRS SADARM	.377
		155 LT WT	.292	AIR VOLCANO	.374
		ARV	.292	ATAS	.355
		155 ER	.275	WAM	.354
		AMS-H	.249	ADV QUICKFIX	.345
		155 TGP	.230	AFAS	.334
		M1A2	.187	MLRS TGW	.331
				ARV	.295
				155 LT WT	.294
				155 ER	.277
				AMS-H	.250
				155 TGP	.230
				M1A2	.189
				FIFV	.162

Table 6-10. VAA System Coefficients for Contingency and Stressful Scenarios (combined explicit)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
WAM	.838	ADATS	.712	FIFV	.856
AAWS-M	.678	MLRS TGW	.638	RAH-66 LB	.653
ADV QUICKFIX	.579	M1A2	.615	RAH-66	.631
ADATS	.575	HAB	.536	AH-64 LB	.583
JSTARS	.492	RAH-66	.534	MLRS TGW	.499
AIR VOLCANO	.475	AH-64 LB	.527	ADATS	.493
ATAS	.454	GBS	.524	AFAS	.425
HAB	.442	WAM	.505	GBCS-L/H	.424
MLRS SADARM	.395	ATAS	.435	TOW2B	.416
PLS	.393	ADV FF	.388	HAB	.401
GBCS-L/H	.285	AVENGER	.388	AIR VOLCANO	.398
HET	.273	ATACMS II	.351	FMTV5	.389
TOW2B	.269	ARV	.343	FMTV2.5	.389
AVENGER	.265	155 ER	.339	GBS	.388
ARV	.258	155 TGP	.327	WAM	.387
M1A2	.247	NLOS-AT	.325	AAWS-M	.376
VEMASID	.242	155 LT WT	.324	HET	.368
GND VOLCANO	.210	HET	.315	STINGRAY	.352
FMTV5	.181	GBCS-L/H	.307	JSTARS	.348
FMTV2.5	.181	JSTARS	.300	155 LT WT	.348
		AMS-H	.272	FARV-A	.340
		AAWS-M	.261	155 TGP	.337
		TOW2B	.249	PLS	.335
		GND VOLCANO	.247	BLOCK III	.332
		STINGRAY	.244	VEMASID	.324
		PLS	.240	155 ER	.313
		LOSAT	.221	ADV QUICKFIX	.312
		ADV QUICKFIX	.220	AVENGER	.280
		MLRS SADARM	.216	M1A2	.277
		FMTV5	.216	ADV FF	.272
		FMTV2.5	.216	AMS-H	.271
		AIR VOLCANO	.201	ATACMS II	.268
		VEMASID	.189	MLRS SADARM	.262
				GND VOLCANO	.237
				ADV SEMA	.235
				ARV	.212
				NLOS-AT	.211
				ATAS	.209
				LOSAT	.173
				AGS	.167
				CMV	.141

Table 6-11. VAA System Coefficients for Contingency and Stressful Scenarios (combined implicit and explicit)

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
WAM	.837	ADATS	.712	FIFV	.855
AAWS-M	.678	MLRS TGW	.637	RAH-66 LB	.653
ADV QUICKFIX	.578	M1A2	.615	RAH-66	.631
ADATS	.575	HAB	.536	AH-64 LB	.583
JSTARS	.492	RAH-66	.534	MLRS TGW	.498
AIR VOLCANO	.475	AH-64 LB	.527	ADATS	.493
ATAS	.454	GBS	.524	AFAS	.425
HAB	.442	WAM	.505	GBCS-L/H	.425
MLRS SADARM	.395	ATAS	.435	TOW2B	.416
PLS	.393	ADV FF	.388	HAB	.401
GBCS-L/H	.285	AVENGER	.388	AIR VOLCANO	.398
HET	.273	ATACMS II	.351	FMTV5	.389
TOW2B	.269	ARV	.343	FMTV2.5	.389
AVENGER	.266	155 ER	.339	GBS	.388
ARV	.258	155 TGP	.327	WAM	.387
M1A2	.247	NLOS-AT	.325	AAWS-M	.376
VEMASID	.242	155 LT WT	.324	HET	.368
GND VOLCANO	.211	HET	.315	STINGRAY	.352
FMTV5	.182	GBCS-L/H	.307	JSTARS	.348
FMTV2.5	.182	JSTARS	.301	155 LT WT	.347
		AMS-H	.272	FARV-A	.340
		AAWS-M	.262	155 TGP	.337
		TOW2B	.249	PLS	.336
		GND VOLCANO	.247	BLOCK III	.332
		STINGRAY	.245	VEMASID	.324
		PLS	.241	155 ER	.313
		LOSAT	.222	ADV QUICKFIX	.312
		ADV QUICKFIX	.220	AVENGER	.280
		FMTV5	.217	M1A2	.277
		FMTV2.5	.217	ADV FF	.273
		MLRS SADARM	.216	AMS-H	.271
		AIR VOLCANO	.202	ATACMS II	.269
		VEMASID	.189	MLRS SADARM	.262
		AGS	.017	GND VOLCANO	.238
				ADV SEMA	.235
				ARV	.212
				NLOS-AT	.211
				ATAS	.201
				LOSAT	.174
				AGS	.168
				CMV	.142

c. Limitations of Coefficients. TOPSIS coefficients are used as measures of system benefit in the Optimization Module. This use has been questioned. It is felt by some that while TOPSIS coefficients represent relative ranking among the alternatives, they do not necessarily provide measures of the magnitude of difference between alternatives. Further study of this area is ongoing.

6-4. SENSITIVITY ANALYSIS. Two areas of analysis evaluated the effect of changes in criteria weights on computed system coefficients. The first area examined the sensitivity of computed coefficients to effectiveness criteria weights only. The second area looked at the sensitivity of computed coefficients to all criteria weights. In the latter case, coefficients were computed with and without weights and compared for discernible differences.

a. Sensitivity of Computed Coefficients to Effectiveness Weights Only. VAA coefficients appear to be highly correlated with the explicit effectiveness factors. One might anticipate this, since the surveyed decisionmakers assigned greater weight to explicit measures (0.767) than to implicit measures (0.233).

(1) Methodology. To assess the sensitivity of VAA coefficients to changes in the effectiveness weights, the ratio of implicit-to-explicit weight was allowed to vary while all other criteria weights were held constant. The effectiveness weight ratio was varied by successively adding 10 percent to the base implicit weight (0.23) and subtracting 10 percent from the base explicit weight (0.77). Effectiveness weights that were evaluated in the sensitivity analysis ranged from the base implicit-to-explicit ratio of 0.233/0.767 to a ratio of 0.93/0.07.

(2) Results and Observations. Figure 6-5 shows system coefficients that were computed for selected effectiveness weight ratios. In general, effectiveness weights appear to affect the coefficients. However, the coefficients do not appear very sensitive to small changes in implicit weights. Some specific observations follow.

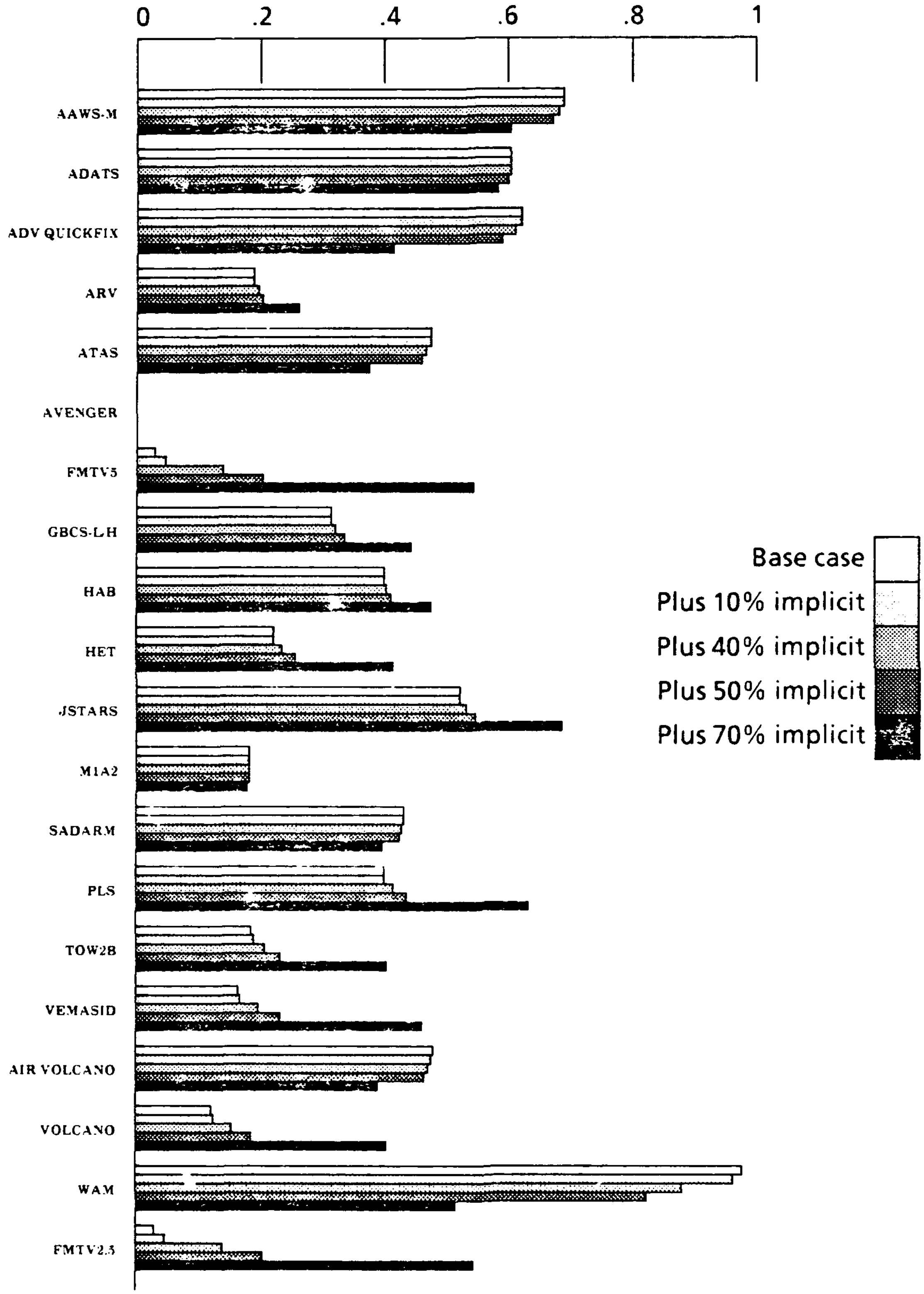


Figure 6-5. Variation in the 1996 Contingency Scenario Coefficients as Effectiveness Weights

(a) The rank ordering of the 20 systems did not change when the base effectiveness ratio was changed by 10 percent. There were slight changes in the coefficients computed for only a few systems, namely, the family of medium tactical vehicles (FMTV) (5-ton and 2.5-ton) trucks and the WAM system.

(b) The rank ordering of the 20 systems changed when the ratio of effectiveness weights changed by 50 percent. In this case, the effectiveness weights were reversed (i.e., the implicit weight became 0.737 and the explicit weight became 0.233). Actual changes in the coefficients were still relatively small for most systems. The larger changes occurred for top rated WAM, whose coefficient decreased to 0.82 and for the FMTV, whose coefficient increased almost tenfold (from 0.028 to 0.21).

(c) Systems such as the Air Defense Antitank System (ADATS), M1A2 Abrams main battle tank, and SADARM appear basically unaffected by changes in implicit factor weights, whereas the value of FMTVs appear to increase as the weight of implicit factors increased.

(d) Changes in system coefficients became statistically discernible at the extreme of the ratio range (i.e., implicit is 0.093 and explicit is 0.07) for most systems at an 80 percent confidence level.

b. Sensitivity of Computed Coefficients to All Criteria Weights. There are references in the literature that suggest criteria weights may have little effect on the coefficients computed with multiattribute utility models. This premise was evaluated for selected Phase II results.

(1) **Methodology.** System coefficients were computed for the Contingency Scenario 96 with all criteria weights set to 1.0 and compared to the base case Contingency Scenario 96 coefficients that were computed with the survey criteria weights. Since criteria weights are scaler multipliers, setting all weights to 1 is equivalent to computing the coefficients without weights.

(2) **Results and Observations.** Table 6-12 compares the system coefficients computed without weights to the base case coefficients computed with survey weights. Observations from this comparison are:

(a) The relative overall ranking of systems changed when weights were not used. However, the seven top ranked systems were the same for the base case and the "no weights" case. FMTVs and a few other systems moved up slightly in rank.

(b) There were discernible differences in the coefficients computed with and without weights for individual systems as shown in Table 6-12. While the differences do not appear to be statistically significant based on standard parametric and nonparametric tests, the data observations suggest that weights do have an effect on rank order. The test of hypothesis about difference in means was used as the parametric test of significance. Nonparametric tests used were the Sign test and the Wilcoxon Matched-Pairs Signed-Rank Test.

Table 6-12. Changes in Contingency 96 System Rank With and Without Criteria Weights

Rank	Base case		No weights	
	System name	Coefficients	System name	Coefficients
1	WAM	.976	WAM	.819
2	AAWS-M	.689	AAWS-M	.624
3	ADV QUICKFIX	.623	ADV QUICKFIX	.586
4	ADATS	.605	ADATS	.557
5	JSTARS	.520	JSTARS	.531
6	AIR VOLCANO	.477	AIR VOLCANO	.478
7	ATAS	.474	ATAS	.464
8	SADARM	.431	PLS	.433
9	PLS	.401	HAB	.423
10	HAB	.400	SADARM	.413
11	GBCS-L/H	.315	GBCS-L/H	.334
12	HET	.221	TOW2B	.305
13	ARV	.190	HET	.298
14	TOW2B	.187	VEMASID	.243
15	M1A2	.184	VOLCANO	.226
16	VEMASID	.164	FMTV5	.220
17	VOLCANO	.122	FMTV2.5	.220
18	FMTV5	.028	ARV	.220
19	FMTV2.5	.028	M1A2	.177

6-5. FUTURE DEVELOPMENT. Future developments for the Effectiveness Integration Module will study the apparent insensitivity of overall system coefficients to effectiveness weights. There will be further evaluation of alternatives to the TOPSIS tool. Currently, the AHP is used to compute criteria weights, and TOPSIS is used to combine the system criteria scores into an overall system score that is weighted by the criteria weights. Expert Choice Software for AHP's rating modules is a recommended approach when the number of alternatives is too many for effective pairwise comparisons.

6-6. SUMMARY. TOPSIS is a MADM tool that is popular within the Army. VAA used TOPSIS to integrate the values that a system contributes to the fulfillment of the various decision criteria into an overall measure of the system's benefit. These overall measures are highly correlated with the explicit measures of effectiveness derived from the combat simulations. This correlation coincides with the expectation extrapolated from decisionmaker surveys. The strong correlation observed between the overall coefficients and the combat simulated MOE suggests that the coefficients can be used with some confidence despite the limitation discussed in paragraph 6-3c. Furthermore, the sensitivity analysis that was conducted suggests that the coefficients do not fluctuate greatly for small changes in the inputs.

CHAPTER 7

COSTING

7-1. INTRODUCTION

a. The purpose of the costing process is to provide accurate cost input to the Value Added Analysis optimization model that will result in reliable cost outputs for a wide range of applications. Weapon system cost-quantity relationships, weapon system categorizations, impacts on appropriations, and formulation of budget constrains applicable to VAA systems were considered in the costing process. Figure 7-1 provides an overview of the costing process.

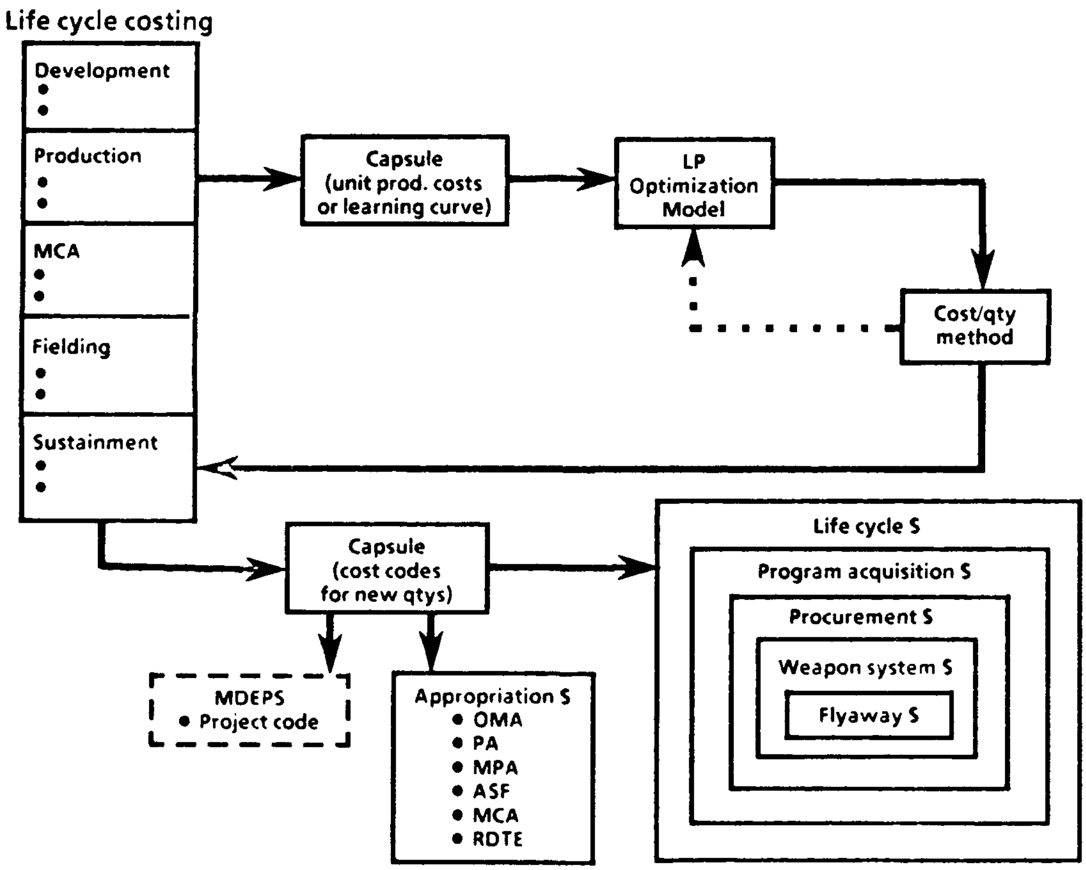


Figure 7-1. Overview of Value Added Analysis Costing Process

b. Baseline RDTE and procurement costs for VAA systems are provided as input to the VAA optimization model. With respect to procurement costs, systems are categorized as to whether cost-quantity curves (e.g., learning curve) are used. First unit costs (FUCs) and cost-quantity curves are provided for those systems for which this data was available and applicable. ("Cost-quantity" reflects economies of scale

in terms of materials and labor as opposed to exclusive "learning" on the part of the production labor force.) Average unit procurement costs are used for the remaining systems. Budget constraints are determined by applying a ratio, representing the proportion of Value Added systems to the total RDA budget, to a fixed total obligational authority provided by the sponsor.

c. Cost-quantity relationships are dynamically computed in the VAA optimization. A detailed discussion of this process is provided in Chapter 8.

d. Life cycle costs are based on the baseline cost estimate P-92 cost code structure. This breakdown allows for computation of weapon system and appropriation categories.

7-2. COST DATA SOURCES

a. Complete life cycle cost data were requested from the US Army Cost and Economic Analysis Center (CEAC) for all VAA weapon systems to use for the P-92 cost categories used for the standard VAA LCCM template shown in Appendix E. These data were extracted from the executive summary portions of the BCE or Army cost position (ACP), whichever provided the most current data. BCE/ACP data were not available for those developmental systems that did not reach Milestone 2 (Development Approval), at which time a BCE is required. Systems at Milestones 0 and 1 generally had only RDTE and procurement cost estimates. Figure 7-2 illustrates the acquisition milestones and phases for a weapon system. Table 7-1 defines the cost categories for the LCCM.

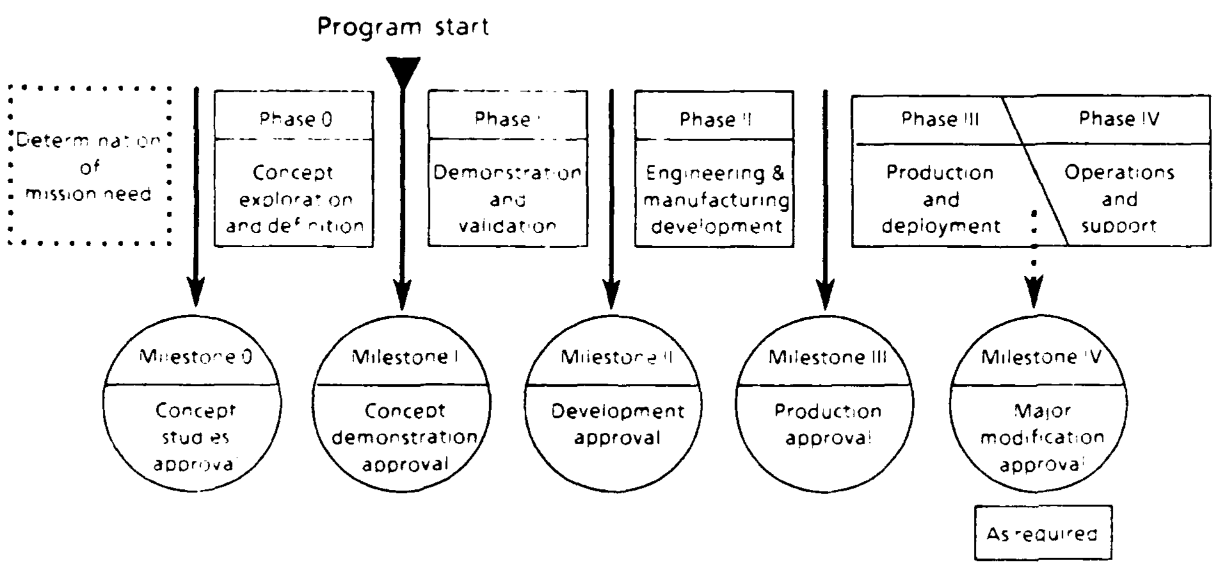


Figure 7-2. Acquisition Milestones and Phases

Table 7-1. Major Weapon System Cost Code Definitions

Major weapon system definition	LCCM cost elements
Flyaway cost Manufacturing Engineering Tooling Quality control Nonrecurring "startup" Allowance for changes Other	Flyaway cost 2.021 Manufacturing 2.022 Rec engineering 2.023 Tooling 2.024 Quality control 2.01 Nonrecurring 2.03 Engineering changes 2.05 System test & evaluation 2.091 System project management 2.094 Other production cost
Weapon system cost Flyaway cost Technical data Contractor services Support equipment Training equipment/factory tng Other	Weapon system cost Flyaway cost 2.04 Data 2.09 Peculiar support equip ASIOE 2.06 Training services & equipment 2.08 Operational site activity
Procurement costs Weapon system costs plus Initial spares Other	Procurement costs Weapon system costs plus 2.07 Initial spares 4.0 Fielding (procurement)
Program acquisition costs Procurement costs plus RDTE Facility construction	Program acquisition costs Procurement costs plus 1.0 Development 3.0 Military construction
Life cycle costs Program acquisition costs	Life cycle costs Program acquisition costs
Operations & support	5.0 Sustainment + 4.0 Fielding (OMA)
Common support equipment	2.092 Common equip (ASIOE) + 2.093 OSE
Disposal	N/A
	Total life cycle costs

b. Most of the data were provided in the form of BCEs from the program managers (PMs) through CEAC. Other sources included the Assistant Secretary of the Army for Research, Development, and Acquisition (ASARDA), Army Materiel Command (AMC), and ODCSOPS. Cost-quantity curves and FUCs were obtained from the PMs or derived from production data by CAA, when applicable.

c. BCEs are not provided in consistent formats. Hence, there were significant gaps in the LCCM data for some systems. In some instances, portions of the data provided in a BCE were extrapolated by CAA to provide complete life cycle costs (see paragraph 7-3b).

7-3. VAA COSTING ASSUMPTIONS. The following assumptions were made for all systems in the VAA optimization input and life cycle costing processes.

a. VAA Optimization Input

(1) The following production costs vary directly with production quantity: recurring engineering, tooling, quality control, initial spares, and training services and equipment.

(2) The following production costs do not vary directly with production quantity: nonrecurring, engineering changes, data system evaluation, operation of site activity, other production excluding peculiar associated items of equipment (ASIOE), and organization support equipment (OSE).

b. Life Cycle Costing

(1) RDTE and MCA costs remain constant with the baseline and do not change with varying production schemes.

(2) Analogous system cost data can be applied to future system cost data when future system cost data are not available.

(3) Proportional unit costs, by P-92 cost data, from BCE/ACP baseline costs can be applied to new production quantities.

(4) Fielding will take place 2 years after production.

(5) Operation and sustainment costs are based on cumulative fielding of weapons systems.

(6) O&S cost buildup begins when the first system produced is fielded.

(7) When transportation costs do not distinguish between first destination transportation (FDT) costs and second destination transportation (SDT) costs, FDT comprise 1/3 of the transportation costs and SDT comprise 2/3 of the total transportation costs.

7-4. VAA COSTING LIMITATIONS. The following limitations are applicable to the optimization input and life cycle costing processes.

a. VAA Optimization Input

(1) Economies of scale are reflected by existing or derived composite cost-quantity curves.

(2) BCE/ACP data are used for VAA base case unit production costs and quantities.

(3) FUCs and cost-quantity curves for weapon systems are applied to the total system rather than a summation of costs resulting in the application of system component cost-quantity curves and FUCs.

(4) Average unit procurement costs are used when cost-quantity curves are not available (as was the case for some pre-Milestone 2 systems) or appropriate (as was the case for some combat service support (CSS) mission area systems).

b. Life Cycle Costing

(1) Production, fielding, and sustainment P-92 subelements for optimized quantities are calculated based on the same proportions as the baseline.

(2) Data for previous years and outyears (years beyond 2008) are grouped.

(3) Costs for the outyears are based on the difference between the costs prior to 2009 and the total costs provided.

(4) Categories of Procurement, Army (PA) appropriations are not provided (i.e., missiles, aircraft).

7-5. VAA OPTIMIZATION INPUT

a. The input cost data to the VAA optimization model are provided in constant FY 92 dollars. For systems with cost-quantity curves, the input data include previously produced quantities, first unit costs (FUCs), and the cost-quantity slope coefficient for recurring manufacturing costs, annual variable unit costs, and annual fixed costs. Recurring manufacturing cost is a key production cost driver. A sample of FUCs and cost-quantity curves used is shown in Table 7-2. This data reflects recurring manufacturing costs except for five ASM systems (Block III, future infantry fighting vehicle (FIFV), combat mobility vehicle (CMV), future armored resupply vehicle-artillery (FARV-A), and Advanced Field Artillery System (AFAS)) which reflect total production costs for a revamped ASM program. Other exceptions are footnoted in the table.

Table 7-2. First Unit Costs and Cost-quantity Curves

System	First unit cost (constant FY 92 $M)	Cost-qty curve (percent)	Prior qtys (prior to FY 94)
AMS-H[a]	$.0657	87.7	
AAWS-M	.1796	87.7	
ADATS	11.38	92.5	11
ATAS	.068	93.3	
AVENGER	.90	97.1	629
SADARM (MLRS)	.4363	86.5	
VEMASID[b]	.0657	94.6	540
AGS[b]	2.7	95.3	
ATACMS II	2.45	89.5	
GBS	4.92	88.9	
NLOS-AT	2.88	94.1	
LOSAT	11.27	91.3	
STINGRAY	1.28	87.6	
AFAS	15.73	90.0	
BLOCK III	34.4	90.0	
CMV	15.47	90.0	
FARV-A	8.89	90.0	
FIFV	35.7	90.0	
RAH-66	37.79	87.5	

[a]Reflects total recurring costs.
[b]Reflects total production costs.

b. Table 7-3 provides the P-92 cost categories that are considered fixed costs and those considered variable costs. Thus, the annual procurement costs for optimized quantities were calculated by summing the recurring manufacturing costs (computed from the first unit cost and cost-quantity slope), the unit variable costs (multiplied by the new quantity), and the fixed costs by year.

Table 7-3. Composition of Procurement (-) Costs

```
 PROCUREMENT COSTS (-) =

    RECURRING MANUFACTURING COSTS + VARIABLE COSTS + FIXED COSTS

Recurring Costs = 2.021 Recurring Manufacturing Costs based on
                    Learning Costs.

Variable Costs  = 2.022 Recurring Engineering + 2.023 Tooling
                + 2.024 Quality Control + 2.06 Training Services
                + 2.07 Initial Spares.

Fixed Costs     = 2.01 Nonrecurring Costs + 2.03 Engineering Changes
                + 2.04 Data + 2.05 System Evaluation
                + 2.08 Operate Site Activity
                + 2.09 Other Production (excluding 2.092 Peculiar ASIOE and
                  2.093 Organizational Support Equipment).
```

c. Procurement (-) costs for VAA Phase II drills exclude associated support items of equipment (ASIOE) and procurement funded fielding to be consistent with what is included in the MDEPs identified with weapon systems. ASIOE and procurement funded fielding cannot always be directly correlated with a specific weapon system MDEP.

d. A software package developed for the Air Force called LCURVE (LCURVE, Version 1.3, Telecote Research, Inc., 15 Feb 91) was used to derive cost-quantity curves for most systems. A detailed explanation of the derivation of cost-quantity curves is provided in Appendix F of the VAA Phase I Study Report. FUCs and cost-quantity curves that were derived were rejected if the coefficient of determination (R^2) was less than 85 percent or if resulting curves were lower than 85 percent (This was based on discussions with CEAC and PMs). In most cases, cost-quantity curves were applied to recurring manufacturing costs only, with the remaining costs treated as fixed production costs by year or unit variable costs. In other instances, detailed production costs were not available, and total recurring manufacturing costs or total production costs were used to derive a cost-quantity curve.

e. Average unit procurement costs by year were derived from the baseline (i.e., BCE) for weapon systems for which cost-quantity curves were not used. Procurement costs for those systems without cost-quantity curves were computed by multiplying average unit production costs by optimized quantities.

f. Procurement costs for VAA weapon systems were modified to exclude ASIOE and OSE and then added to RDTE costs to compute a program acquisition (-) cost consistent with the MDEP appropriation configuration of systems in the LRRDAP data structure. Procurement funded fielding costs and MCA costs were also excluded from the program acquisition (-) cost calculation.

g. An algorithm to dynamically account for cost-quantity curves was incorporated in the optimization model. An explanation as to how the optimization model dynamically computes costs is provided in Chapter 8.

h. Annual minimum sustainment rates (MSRs) and maximum production rates (MPRs) were obtained from procurement forms' (P-form) data. MSRs/MPRs for systems without P-form data were provided by ASARDA and from data provided by PMs to AMC.

(1) MSR is defined as a level of production which will keep a production line open while maintaining a responsive vendor and supplier base (i.e., warm production base). The assumption inherent in the MSR is that the plant must operate one shift, 8 hours per shift, 5 days a week. Conversely, the MPR is defined as a level of production which maximizes the capacity of the existing tooling or facilities without requiring an additional investment to increase the production capacity. This definition assumes three shifts of 8 hours per shift, 7 days a week.

(2) MSRs and MPRs for some systems were adjusted to reflect a ramp-up to full-scale production, based upon baseline procurement quantities.

(3) It should be reiterated that, for the VAA Phase II drills, the optimization model was constrained to procure the total force structure requirement as defined by the sponsor. If the force structure requirement was not met, then the system was not procured. Force structure requirements are shown in Chapter 4. Production constraints were not available for a few developmental systems and were set based on analogous systems and planned production schedules. Table 7-4 provides the MSRs and MPRs used by each system.

Table 7-4. Annual MSRs and MPRs Used in VAA Optimization Model (page 1 of 2 pages)

System	Annual MSR (each)	Annual MPR (each)
AAWS-M	996	20,000
ADATS	12	72
ADV QUICKFIX	5	100
ARV	50	100
ATAS	36	480
AVENGER	24	280
FMTV 5-TON	250	2,500
GBCS-L/H	3	50
HAB	20	100
HET	150	500
JSTARS	5	15
M1A2	120	1,440
SADARM (MLRS)	1,200	7,500
PLS	280	3,000
TOW 2B	8,000	36,000
VEMASID	30	150
GROUND VOLCANO	21,000	135,000
AIR VOLCANO	21,000	135,000
WAM	1,800	4,667
155 ER	4,176	35,280
155 LT WT	24	192
155 TGP	348	2,940
ADV FIREFINDER	3	10

Table 7-4. Annual MSRs and MPRs Used in VAA Optimization Model (page 2 of 2 pages)

System	Annual MSR (each)	Annual MPR (each)
AGS	24	360
AH-64 LB[a]	48	144
AMS-H[a]	2,000	25,000
ATACMS II	240	864
GBS	12	48
LOSAT[a]	34	114
MLRS TGW	1,200	4,000
NLOS-AT	36	422
RAH-66[a]	72	168
STINGRAY	15	60
ADV SEMA	3	25
AFAS[a]	72	228
BLOCK III[a]	240	636
CMV[a]	48	76
FARV-A[a]	72	228
FIFV[a]	72	228
RAH-66 LB[a]	48	144
FMTV 2 1/2-TON	515	3,250

[a]NOTE: annual ramp-up constraints were used for these systems.

7-6. ANNUAL TOA BUDGET CONSTRAINT COMPUTATION

a. A series of optimization runs was performed to support the LRRDAP budget drill process. An estimated budget constraint was produced to allocate the proportion of a given RDA TOA to VAA systems, as illustrated in Figure 7-3.

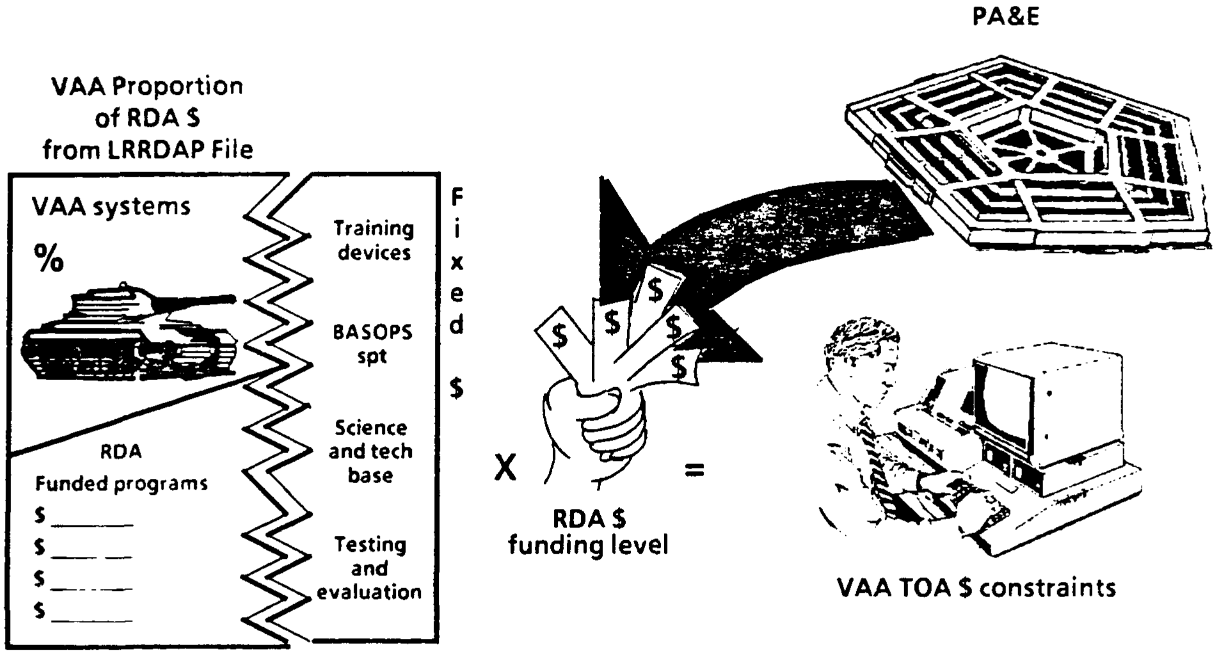


Figure 7-3. Annual TOA Budget Constraint Computation

b. TOA was provided by standard study number (SSN) for procurement dollars and program element (PE) for RDTE dollars in the LRRDAP data base. The MDEP codes were manually examined along with the appropriate PEs and SSNs and assigned to the respective VAA weapon category. The current dollars were then deflated to constant FY 92 dollars. A proportion of VAA system dollars to total TOA, excluding dollars designated as "fixed" by PA&E (technology base, base operations support, test and evaluation, and training devices) was used to estimate the TOA constraint for the VAA portion of the RDA account.

(1) The first step was to sum the RDA (including RDTE, Procurement, Army (PA), Other Procurement, Army (OPA), missiles, wheeled and tracked vehicles (WTCV), aircraft, etc.) dollars in the particular version of LRRDAP being addressed for each year of the POM and EPP for VAA systems (FY 94 to FY 08). There was a very small margin of error in this calculation, since some MDEPs (i.e., trucks, mines, etc.) are attributed to multiple systems.

(2) The second step was to calculate the total RDA dollars for all MDEPs reflected in the LRRDAP for both the POM and EPP years.

(3) Fixed costs were subtracted from the total RDA ($), and a ratio was derived based on the proportion of dollars assigned to VAA systems dollars to the total RDA ($) minus the fixed portion. This ratio was applied to a given annual TOA constraint (e.g., $12.7 billion per year). This fixed annual TOA constraint in the EPP was inflated based on the latest OSD inflation guidance of 3.2 percent per annum.

7-7. LIFE CYCLE COSTING

a. Introduction. Life cycle costs were based on the BCE P-92 cost code structure. Table E-1 depicts the P-92 codes and corresponding appropriations used in the life cycle costing. The LCCM used in VAA is a Quattro Pro spreadsheet model that provides the analyst a quick estimate of the impacts that changes in procurement quantities have on the various P-92 cost elements, appropriations, and categories of weapon system costs. The upper portion of the spreadsheet (LCCM1) contains the P-92 cost code data obtained from BCE/ACP data; and the lower part (LCCM2) provides proportional estimates of the same P-92 cost code data for new procurement quantities, based on the original BCE/ACP data relationship. Appendix E provides an example of LCCM1 and LCCM2.

b. Life Cycle Cost Model. The upper part of the LCCM (LCCM1) contains the BCE/ACP data and drives the lower part (LCCM2), which provides the life cycle cost estimates for the optimized quantities. The entire LCCM is driven by two pieces of input data: annual average unit production cost and the associated optimized quantities. This data is obtained from the optimization model output. As discussed earlier in the the cost-quantity methodology, the optimization model considers the effects of "learning" and "economies of scale." Some minor adjustment to the output costs may be required in applications where ASIOE and OSE are removed, as was the case in the VAA support for the LRRDAP drills (production costs include ASIOE and OSE costs).

(1) RDTE and MCA Cost. The 1.0 RDTE and 3.0 MCA costs are considered fixed costs regardless of production quantities. Thus, the costs for LCCM2 are identical to the LCCM1 baseline. Generally, MCA costs were absent from the BCE/ACP.

(2) Production Costs. The 2.0 production costs and quantities are obtained from the optimization results. The equation that represents the LCCM2 2.0 production cost stubs is as follows:

$$\frac{LCCM2\ 2.0\ Optimized\ Production\ Qty}{LCCM1\ 2.0\ Baseline\ Production\ Qty} * (LCCM1\ 2.0\ P-92\ cost\ code)$$

When there are costs associated with 2.0 production cost categories and no quantities in LCCM1, these costs are carried over to LCCM2 directly without proportional adjustment. These are startup costs prior to production and assumed to be unchanged by the variation in the production scheme.

(3) **Fielding Costs.** Fielding quantities are taken from the production schedule based on the annual optimized quantities and shifted 2 years in the future. The assumption is that fielding will occur 2 years after production. As with production cost stubs, a proportional calculation for the 4.0 fielding cost stubs was made based on the LCCM1 baseline:

$$\frac{LCCM2\ 4.0\ New\ Fielding\ Qty}{LCCM1\ 4.0\ Baseline\ Fielding\ Qty} * (LCCM1\ 4.0\ P-92\ cost\ code)$$

(4) **Sustainment Costs.** Sustainment quantities are calculated similar to the cumulative fielding quantities with sustainment costs being incurred in the first year of fielding. Again, costs are proportionally derived from the LCCM1 baseline:

$$\frac{LCCM2\ 5.0\ New\ Sustainment\ Qty}{LCCM1\ 5.0\ Baseline\ Sustainment\ Qty} * (LCCM1\ 5.0\ P-92\ cost\ code)$$

c. Inflation. Procurement and RDTE costs for weapon systems obtained in constant dollars were inflated using composite indices from AMC guidance. The composite index, used when including inflation in TOA, not only incorporates the mathematical principle of compounding, but also takes into consideration outlay rates and the impact of inflation over the entire spending pattern. Compound indices were applied to OMA, MPA, and MCA funded life cycle costs when required.

d. Major Weapon Systems Cost Categories. The following five major weapon system cost categories were computed from the baseline: flyaway, weapon system, procurement, program acquisition, and total life cycle costs. The composition of these major weapon system cost categories is provided in Table 7-4.

e. Appropriations. The RDTE, PA, OMA, Army Stock Fund (ASF), and MPA appropriations are calculated by summing the P-92 cost codes by appropriation.

f. Data Quality. Each spreadsheet for a weapon system was categorized as to the completeness of the data as follows:

(1) Category A - comprehensive data obtained from BCE.

(2) Category B - data from BCE, but either some extrapolation by CAA or significant gaps in the data.

(3) Category C - data largely limited to rolled RDTE and production costs. This category consists of mostly very developmental systems that are not at the stage requiring a BCE.

g. Validation. Proportional factors from the February 1990 ASM BCE were compared to the cost codes provided in the later April 1990 ASM BCE for reduced quantities. Comparisons were made for the Block III tank, FIFV, CMV, FARV-A, and AFAS. Proportions remained relatively constant, under 5 percent deviation for most P-92 cost codes. Table 7-5 shows the deviations of the estimated costs using the computed proportional factors compared to the updated ASM BCE.

Table 7-5. Block III Comparison

P-92 cost codes	BLK III Comparison	FY 01	FY 02	FY 03	FY 04
2.01	Nonrecur	0.3%	0.3%	0.3%	0.4%
2.02	Recur	2.4%	2.9%	2.7%	3.5%
2.021	Manufacturing	4.0%	4.8%	4.3%	5.5%
2.022	Recurring Engineering	0.9%	1.1%	1.0%	1.2%
2.023	Tooling	0.4%	0.4%	0.4%	0.5%
2.024	Quality Control	0.2%	0.3%	0.3%	0.3%
2.03	Engineering Changes	0.2%	0.2%	0.2%	0.4%
2.04	Data	0.7%	0.8%	0.7%	0.9%
2.05	Sys Test & Eval	0.1%	0.1%	0.1%	0.2%
2.06	Training Serv & Equip	0.0%	0.2%	0.2%	0.1%
2.07	Initial Spares	0.2%	0.1%	0.2%	0.5%
2.09	Other Proc Funded Prod	0.9%	1.2%	1.0%	1.3%
4.02	Training, Serv & Equip	2.6%	1.3%	2.0%	2.1%
4.03	Transportation	1.7%	1.5%	1.5%	1.5%
4.04	Initial Repair Parts	4.3%	2.9%	3.5%	3.6%
5.01	Replenishment	3.9%	7.1%	7.0%	6.7%
5.02	Petrol,Oil,Lubricants	0.0%	0.0%	0.0%	0.0%
5.03	Ammo/Msl	2.8%	8.5%	6.6%	5.4%
5.04	Depot Maintenance	1.8%	1.0%	0.8%	0.8%
5.041	Depot Maint Civ. Labor	0.7%	0.4%	0.3%	0.3%
5.05	Field Maint Civ. Labor	0.0%	0.0%	0.0%	0.0%
5.06	Transportation	0.0%	0.1%	0.1%	0.1%
5.07	Repl Training	2.7%	1.3%	0.8%	0.6%
5.08	MPA	0.3%	1.2%	2.4%	3.0%
5.09	Sys/Proj Mgmt(Civ)	0.9%	0.3%	0.2%	0.2%
5.10	Modifications/Kits	1.3%	0.2%	0.4%	0.3%
5.11	Other Sustainment	0.3%	0.1%	0.1%	0.0%
5.111	Other OMA Funded	0.3%	0.2%	0.2%	0.2%
5.112	Other PA Funded	0.0%	0.0%	0.1%	0.1%

NOTE: Block III quantities were 3,349 in Feb 91 BCE and 1,946 in April 1991 BCE. Annual production rates compared above are 500 per year versus 300 per year.

The percent differences between cost code proportion of total production, fielding, and sustainment costs are shown in Table 7-5 comparing the Block III February 1991 BCE to the Block III April 1991 BCE.

h. LCCM-Shift. This paragraph summarizes the process that was used to develop a condensed life cycle cost model that automatically adjusts cost with shifts in production schedules. Currently, the condensed Life Cycle Cost Model (LCCM-Shift) is planned for use in VAA Phase III.

(1) One of the advantages of using this revised spreadsheet version is to provide the flexibility of having a quick turnaround of pertinent cost data with the capability of revising planned production schedules. This spreadsheet is unlike the original LCCM, which is extracted from a greater level of detail from a weapon system's BCE. Dollars are adjusted for different years with scheduled production shifts from the beginning of the POM until the end of the EPP (FY 94 - FY 08), for any combination of years.

(2) The spreadsheet model uses several macros within a Quattro Pro spreadsheet. The data is based on the most appropriate data elements from the BCEs of each of the respective systems (see format below). The only user inputs within the macro are the start years where there are both quantities and production dollars for the baseline and revised entries. Again, new quantities and average unit costs must be determined and entered.

(3) The production, fielding, and sustainment costs are based on the ratio of optimization production dollars to corresponding baseline production dollars (first year of baseline versus first year of optimization, etc.). Output is provided in the following formats:

(a) Baseline (constant dollars),

(b) Baseline (current dollars),

(c) Revised entries (constant dollars),

(d) Revised entries (current dollars), and

(e) Revised Big 5 (current dollars).

(4) The dollars for each stub are proportionally inflated or deflated, depending on when the new optimized production plan is scheduled, either before or after the baseline. The deflation/inflation factors are from the updated AMC Inflation Guidance memo dated January 1992.

(5) An illustration of the baseline template is shown in Table 7-6. It is approximately one-third of the size of the original LCCM. System costs in the form of flyaway, weapon system, procurement, program acquisition, and life cycle costs have been derived from historical BCE data for the category A systems (see paragraph 7-7f for description of category A).

Table 7-6. LCCM Shift

Revised LCCM template

P-92 cost category	Cost element
1.0	Development
2.0	Production (total)
	QTY: (primary)
	QTY: (secondary)
2.01	Nonrecur
2.02	Recur
2.021	Manufacturing
2.022	Engineering
2.023	Tooling
2.024	Quality control
2.03	Engineering changes
2.04	Data
2.05	Sys test & eval
2.06	Training serv & equip
2.07	Initial spares
2.08	Operate/site activity
2.09	Other proc funded prod
2.091	System proj mgmt
2.092	Peculiar spt equip
2.092	Common spt equip
2.093	Org support equip
2.094	Other prod cost
2.10	System project mgmt
3.0	Military construction
4.0	Fielding (total)
4.0	Fielding (OMA)
4.0	Fielding (PA)
5.0	Sustainment (total)
5.0	Sustainment (OMA)
5.0	Sustainment (PA)
5.0	Sustainment (MPA)
5.0	Sustainment (ASF)

7-8. METAPHOR USE

a. The LCCM spreadsheets (baseline data) were exported into the METAPHOR computer at ODCSOPS to provide access for action officers at the Pentagon. The formulas to generate the second part of the LCCM were put in a capsule to generate the life cycle cost for the optimized quantities. CAA can transfer the optimized quantities from the VAA optimization runs to the METAPHOR data base via electronic mail. The LCCM (part 2) on the METAPHOR computer provides the capability for the action officer at the Pentagon to estimate impacts that VAA optimized quantities have on P-92 cost elements, appropriations, and weapon system cost categories. Users can also perform "what if" drills using the METAPHOR computer.

b. Capsules were created to produce standard reports showing the five major cost categories, appropriation categories, and weapon system categories. The goal of this approach is to allow for routine queries and reports of selected data in a variety of formats such as by system or mission area. For example, a listing of all recurring cost production dollars for each system for the total POM period may be of interest. Similarly, a sum of the total life cycle sustainment costs for a selected mission area may be required. Additional reports and queries can be generated as required.

7-9. ASIOE PERSPECTIVE. Major item system maps (MISMs) for approximately 20 VAA systems were obtained from US AMC Systems Integration and Management Activity (USAMC SIMA). These maps provided the ASIOE based on the original basis of issue plan (BOIP) which usually differed from the PM's ASIOE costed in the BCE. Costs by line item number (LIN) were obtained from The Army Force Cost System (TAFCS) data base and can be multiplied by the per-system ratios provided in the MISM. In some instances, ratios were imputed to a per-system factor from a per-unit factor.

7-10. SUMMARY. VAA costs were generated to provide a complete life cycle picture considering cost-quantity relationships and the requirement to meet the quick reaction demands of the POM building process. The VAA costing methodology allows for the capability to produce estimates of procurement costs, RDA costs, VAA system budget constraints, P-92 cost categories, weapon system cost categories, and appropriation categories quickly and within an acceptable degree of accuracy. The cost module is flexible enough to allow for changes in the cost perspective view desired by the decisionmaker. Further refinements are expected with the continued use of the VAA process.

CHAPTER 8

COST EFFECTIVENESS ANALYSIS

8-1. COST EFFECTIVENESS ANALYSIS APPROACH

a. Introduction. The final determination of a recommended acquisition strategy requires the consideration of many factors. These factors include the effectiveness of the systems under consideration, how much the systems cost, the force structure requirement for the systems to fill the force, and the capability of industry to produce the systems. Difficulty has long existed in keeping track of these diverse factors in the process of determining what to procure, in what quantities, and in what timeframes to achieve the most cost effective force possible.

b. Optimization in Value Added Analysis Phase I Study. In the VAA Phase I Study, the decision was made to use mathematical programing to perform this cost effectiveness analysis and to produce a recommended acquisition strategy. A prototype linear programing (LP) formulation was devised for that purpose. This formulation was represented as follows:

Maximize:	Force effectiveness
Subject to:	Budget ceiling
	Force structure requirements
	Production limitations

Although the model was usable and valuable insights were realized through its use, several shortcomings of the prototype formulation were identified during VAA Phase I. First, if insufficient funds were available to procure the minimum required quantities of each system under consideration in each year, the problem would be infeasible. The model had no capability to identify systems that should be "cut" from the program. Since more programs are available for procurement than there are funds available to pay for them, it was clear that some method of identifying systems that should be left unfunded was needed. In VAA Phase I, identification of cuts was performed iteratively based on the cost-benefit ratios of the systems. This process was slow and tedious and did not guarantee optimal results. Second, all costs, including fixed manufacturing costs and RDTE costs, which were not related to quantity had to be included in an annual average unit cost for each system. Third, the model could not handle the so-called "learning curve" costs. These costs are discussed in Chapter 7, and significantly affect the per-unit costs of many systems. Thus, the variable manufacturing costs were often inaccurate.

8-2. ANALYTICAL MODELS AND TOOLS

a. Enhanced Optimization. In order to overcome the above-stated shortcomings, the VALOR Model was developed. VALOR is a mixed integer program (MIP). Since the decision was made to use a MIP formulation, the shortcomings described above could be handled in a relatively standard manner. The details of the VALOR formulation and implementation can be found in the Technical Paper, CAA-TP-92-1. A less detailed discussion of the VALOR Model is given below.

b. Objective Function. The objective of VALOR, and indeed in VAA in general, is to suggest a mix of systems for procurement that will be as effective as possible in combat, subject to constraints on budget, force structure, and production capabilities. The effectiveness of the various candidate systems is evaluated and quantified in the Explicit and Implicit Effectiveness Modules of the VAA methodology, and these various measures are integrated using TOPSIS in the Effectiveness Integration Module to produce the Value Added Coefficient. The result is a single measure of a system's contribution to the effectiveness of the overall force for each scenario and for each year the system will be in the force. These measures are then used to form the objective function coefficients.

(1) **Forming the Objective Coefficients.** This so-called Value Added Coefficient is related to the presence or absence of the system on the battlefield. The combat results are derived using the RSM experimental design and relate to whether or not the entire program is in the force. Whole programs are evaluated in the Implicit Effectiveness Module. Thus, the need existed to convert this measure of "program" effectiveness to a "per-system" measure. This conversion was accomplished by dividing each Value Added Coefficient by the appropriate density of the system played in CORBAN giving a new value which, when multiplied by the quantity of systems to be procured, would give the the effectiveness of the entire quantity. Note that this procedure would not be appropriate unless the quantity of each system procured was related to the CORBAN densities. In VAA, however, procurement quantities are constrained to be the amount necessary to fill some force structure requirement. As such, the unreasonable situation where, for instance, only one item is procured is precluded.

(2) **Coefficients for Intervening Years.** In VAA Phase II, only the years 1996, 2001, and 2008 are explicitly modeled. As such, Value Added Coefficients are computed for those years only. The VALOR Model requires objective coefficients for each system for each year the system can be procured. Ideally each year in the period under consideration would be modeled explicitly. Lacking that, the assumption was made that the effectiveness would vary linearly between the years that explicit modeling is performed. Thus, linear interpolation is used to calculate the objective coefficients for the years that are not explicitly modeled.

(3) **Form of the Objective Function.** The objective function of the VALOR Model can be described as follows. Let v_{ij} be the per-item contribution of the system to force effectiveness, and let x_{ij} be defined as the quantity, of system i procured in year j, where j = 1,..., n, with n being the number of years in the planning horizon. For the VAA Phase II Study, n = 15. The objective function can then be written as

$$\text{Maximize} \sum_{j=1}^{n} \sum_{i=1}^{m} v_{ij} x_{ij}$$

In the analysis, m systems will be considered. For the VAA Phase II Study, m = 41.

c. Budgetary Constraints. Note at the outset that there is a separate budgetary constraint for each year in the time period of interest for the study. Funds designated for use in a particular year cannot be carried over into following years. The model will maximize effectiveness which is accumulated in the objective by the procurement of equipment through the expenditure of funds. The funds available in each year will be specified in these budgetary constraints, so their accuracy is extremely important to obtaining a valid solution.

(1) Total Obligational Authority (TOA). As discussed in Chapter 7, the TOA that can be spent on procuring the systems considered in the VAA Phase II Study is only a percentage of the entire RDA budget. This amount, B_j, gives the constraint on how much can be spent on the candidate systems in each year, and it will be the right-hand side of the budgetary constraint.

(2) Learning Curve Costs. The VALOR Model handles fixed costs, both RDTE and fixed manufacturing costs, linear variable costs or average unit costs, and nonlinear learning curve costs. The method for dealing with learning curve costs is discussed in this subparagraph. Using the power form of the learning curve, the following is an expression for the average unit cost for system i in year j, when the quantity manufactured in year j is considered as the "lot" for that year.

$$C_{ij} = A_i Q_{ij}^{-b_i}$$

where:

$$Q_{ij} = \mathit{lot\ midpoint} = \frac{F_{ij} + L_{ij} + 2\,(F_{ij} L_{ij})^{1/2}}{4}$$

with F_{ij} = accumulated number of the first item of type i produced in year j, L_{ij} = accumulated number of the last item of type i produced in year j,
A_i = the first unit cost of system i, and b_i = the learning curve slope parameter for system i. Notice that C_{ij} is a function of the quantity of system i produced in year j, x_{ij}, as well as the quantities produced in every year through year j - 1. Thus, the learning curve cost term is both nonlinear and not separable. For this reason, an approximation was devised to represent these learning curve cost terms as a piecewise linear approximation to a separable cost function. Thus, each of these learning curve cost terms, $c_{ij}x_{ij}$, gives rise to several new terms in each budgetary constraint, as well as several new constraints involving binary variables. The inclusion of this feature in the VALOR Model greatly increases the complexity of the mathematical programing problem (see CAA-TP-92-1 for details).

(3) Nonlearning Curve Variable Costs. Not all of the systems considered in this study exhibit learning behavior. For these systems, an average unit cost, c_{ij}, is specified for each year of production. The cost term associated with these systems have the form $c_{ij}x_{ij}$, for each year, j, that system i is produced. These terms are then included in the budgetary constraints for appropriate years. Some systems have a component of cost that is more appropriately described as a "nonlearning" variable cost. For these instances, the cost of the system can be described as having both a learning and nonlearning component, and the term $c_{ij}x_{ij}$ can be introduced together with the learning cost in the budgetary constraint.

(4) **Consideration of Fixed Costs.** Some costs, such as RDTE, R_{ij}, expenditures, or nonrecurring fixed manufacturing costs, v_{ij}, are not incurred on a per-unit basis. These costs simply reduce the funds available for procurement (lower the values of the B_j) over the years they are expended. However, when the model is used to evaluate cuts or cancellation of programs, significant savings can be accrued by recouping the RDTE or other fixed cost funds that have not yet been spent. Thus, these costs must be tied to the programs being evaluated in a meaningful way. The discussion of how to handle the evaluation of potential program cancellations will appear later in this chapter.

d. **Force Structure Constraints.** Force structure requirements drive the decisions of how many of a particular item of equipment should be procured. The study sponsor must specify the level of force structure to be considered. For example, the sponsor might know that insufficient funds are available to buy enough for all the force packages, so he may designate that Force Package I, the highest priority group of units in the force, must be filled with equipment for all systems, and that nothing would be procured beyond those needed to fill Force Package II, the next highest priority group of units. Thus, the force structure bounds for each system would be established. It would then be known what the minimum and maximum allowable procurements are for each system by the end of each system's production campaign. For most of VAA Phase II, the sponsors specified that the Force Package I quantities would be procured for any system that was recommended to be procured at all. Later in the study, a range was specified. Also, there are two schemes for specifying constraints on yearly procurement quantities. These schemes are discussed below.

(1) **Equal Quantity Representation.** Of the two ways to represent the force structure constraints in the optimization model, the first involves constraining each year's procurement quantity of each system to be the following:

$$\frac{F_{i_{min}}}{n_i} \le X_{ij} \le \frac{F_{i_{max}}}{n_i}, \forall \textit{ systems i produced in year j}, \forall_j$$

where, for system i,

F_{imin} = minimum force structure requirement,
F_{imax} = maximum force structure requirement,
and n_i = number of years of production.

The advantage of thi· method is that the series of production quantities over the production campaign tends to be more stable. From a practical standpoint, avoiding wide swings in annual production quantities is desirable. The disadvantage is that the constraint is tighter, limiting the flexibility of the model to find a better solution.

(2) Total Quantity Representation. The second option involves constraining the sum of all items produced over the entire production campaign to be between the force structure minimum and maximum. That is,

$$F_{i_{min}} \leq \sum_{j=t_i}^{t_i+n_i-1} \leq F_{i_{max}}, \ \forall_{i,j},$$

where t_i = the first year of production for system i. Constraints on the individual x_{ij}'s would be based on production capacities. These constraints will be discussed later. This option allows for better solutions with respect to the effectiveness objective, but tends to give wide swings in the annual production quantities. The decision regarding which of these schemes to use rests with the study sponsor. Note that the choice of schemes can be made on a system-by-system basis, thus maximizing the flexibility of the model. A modification of this representation is the introduction of additional constraints on the x_{ij}'s that would be used to force a more stable stream of production quantities. Letting P_i be the allowable variation in yearly production quantities, and noting that these constraints would not be applied during ramp-up years, these constraints would take the form

$$(1-\rho_i)X_{i(j-1)} \leq X_{ij} \leq (1+\rho_i)X_{i(j-1)}, \forall_i, \forall_{ti} + 1 \leq j \leq t_i + n_i - 1 \ x_i, j-1$$

In this case, the production quantity would be constrained to be within P_i percent of the previous year's quantity, avoiding undesirable swings in production. Of course, the selection of the percentage is arbitrary and can be adjusted appropriately on a system by system basis.

e. Production Constraints. The capacities of the various production facilities must be considered in constraining the production quantities. Typically, the model is constrained to produce at least the MSR of production and no more than the MPR. The MSR is defined as the production rate needed to keep the production line open while maintaining a responsive vendor and supplier base. The MSR is frequently equated to maintaining a warm production base. The MPR is the production rate which maximizes the production capacity of existing tooling or facilities without requiring additional investment to increase the capacity. Most systems that are not yet in production at the beginning of the planning horizon will have a ramp-up in production over 2 or 3 years where the production capacity is lower than the MSR. The production constraints must be used in conjunction with the force structure constraints to develop the upper and lower bounds of the production quantities, x_{ij}. When using the equal quantity representation of the force structure bounds, some preprocessing is required to ensure that these bounds are applied appropriately. Let

$Pmin_{ij}$ = lower production bound (MSR) for system i in year j,
$Pmax_{ij}$ = upper production bound (MPR) for system i in year j,
$Fmin_{ij}$ = lower force structure bound for system i in year j,
$Fmax_{ij}$ = upper force structure bound for system i in year j,
U_{ij} = upper bound on x_{ij} for system i in year j, and
L_{ij} = lower bound on x_{ij} for system i in year j.

The upper and lower bounds on x_{ij} are determined using the following rules.

(1) If $Pmin_{ij} \leqq Fmin_{ij}$, then $L_{ij} = Pmin_{ij}$.

(2) If $Fmin_{ij} \leqq Pmin_{ij}$, then $L_{ij} = Fmin_{ij}$.

(3) If $Pmax_{ij} \leqq Fmax_{ij}$, then $U_{ij} = Fmax_{ij}$.

(4) If $Fmax_{ij} \leqq Pmax_{ij}$, then $U_{ij} = Pmax_{ij}$.

(5) If $Fmax_{ij} \leqq Pmin_{ij}$, then $L_{ij} = U_{ij} = Pmin_{ij}$.

(6) If $Fmin_{ij} \leqq Pmax_{ij}$, then $L_{ij} = U_{ij} = Pmax_{ij}$.

Note that rules (5) and (6) address the problem of mismatch between the production limitations and the force structure requirements. When these conditions arise, it is prudent to reconsider the length of the production campaign. Note also that the above rules only apply to the first alternative for determining force structure constraints. If the second alternative is employed, namely the total quantity representation, the production bounds are used to bound x_{ij}'s. Care must be taken, however, to ensure that mismatches in the production limitations and force structure requirements are resolved. Otherwise, an infeasible program will result.

f. Evaluation of Program Cuts. As mentioned previously, the model needs to be useful in analyzing program cut alternatives which arise during the building of the Army program and budget. In order to do so, two factors must be considered. First, the procurement of either the quantity of a certain system that conforms to the above constraints or a zero quantity must be feasible. Next, if some fixed costs, such as RDTE funds, are associated with the program, independent of the quantity purchased, then they would also be saved if the program is canceled.

(1) Implementation. In order to implement this enhancement to the model, binary variables were introduced and defined as follows:

$$U_i = \begin{cases} 1, \textit{ if system i is procured,} \\ 0, \textit{ otherwise} \end{cases}$$

Then modify the constraints on the x_{ij}'s as follows.

$$L_{ij}u_i \leqq x_{ij} \leqq U_{ij}u_i.$$

Note that when system i is procured, the $u_i = 1$, and these constraints become equivalent to those previously discussed. When $u_i = 0$, then the value of x_{ij} is constrained to be zero. These binary variables serve two additional purposes. The first is as a switch which turns the fixed costs on and off in the budget constraints, and the second is as a mechanism to relate system procurements.

(2) **Fixed Costs.** If a system is excluded from the list of systems recommended for procurement, its u_i variable will be set at 0. Thus, by including a term in the budget constraint for year j that represents the expenditure of some fixed costs for system i, e.g., $R_{ij}u_i$, the fixed cost will only be assessed against the budget constraint if $u_i = 1$. So these fixed costs do not come into play unless the system is on the recommended list.

(3) **Related System Procurements.** The other important use of these binary u_i variables is to constrain the model to procure systems in combinations. For example, suppose the procurement of a new artillery system and a resupply vehicle that will carry its ammunition is under consideration. It may be necessary to constrain the model to refrain from procuring the resupply vehicle unless it procures the artillery system as well. By introducing the following constraint, the model can be forced to relate these systems as described above.

$$u_{resupply} - u_{artillery} \leq 0.$$

This constraint ensures that the binary variable associated with the artillery system is greater than or equal to that of the resupply vehicle. Thus, the unreasonable result of procuring the resupply vehicle without the artillery system is avoided. The introduction of this type of constraint in various ways allows the analyst to evaluate different combinations of systems. Also, by constraining one of these variables to be either 1 or 0, the analyst can either force a system into or out of the solution, respectively.

8-3. IMPLEMENTATION AND PERFORMANCE

a. Hardware and Software. The VALOR Model was implemented using the IBM Optimization Software Library (OSL), on an IBM RISC 6000 work station. OSL, as the name suggests, is a set of subroutines that can be called to manipulate and solve a variety of optimization problems. It can be accessed through FORTRAN or C programing languages. The software is flexible with respect to input and accepts either standard MPS input format or allows direct access to the data structure to set up the problem.

b. Programming. A front-end application program in FORTRAN that reads the data, processes the data into the appropriate data structures for the optimizer, calls the optimization subroutines, and then prints the results was written to implement the model.

c. Performance

(1) **Early Tests.** The first test problems with realistic data were of the order of 700 rows with 800 variables, of which 350 were binary. This program evaluated approximately 20 systems and took almost 20 minutes of CPU time to run. The model was also run using the system cutting feature; the running time increased 25 - 50 percent. In these early tests, only a small subset of the systems was evaluated as candidates for elimination from the Army budget, usually three or four systems. Also of note was that attempting to evaluate too many such systems greatly increased the run time. Although the run time was increased for most of the runs in which this feature was employed, there were instances where the increase in run time was minimal.

(2) **Performance Tuning.** Several efforts were undertaken to improve the performance of the VALOR Model. The first entailed preprocessing the program using the OSL preprocessing subroutines. This effort had negative results, since the preprocessor could not improve the performance of the model, while additional time was needed to perform the preprocessing step. Next, efforts were undertaken to identify special structure in the formulation that could be exploited. Two classes of strong inequalities were found, which were already implicit in the formulation, but whose explicit inclusion vastly improved the speed of solution. Final test runs, as well as the production runs, were significantly larger than the initials tests that were performed. Ultimately, 41 systems were analyzed, of which 22 had learning curve costs. The mixed integer program had about 4,000 rows with 3,000 variables, of which about 500 were binary integers and 5,500 nonzero elements. The run time for this improved formulation was reduced to between 2 and 13 minutes of CPU time on the IBM RISC 6000 320H. Another important aspect of this improved formulation was that limits on evaluating systems as candidates for elimination were removed. This capability was established to make the procurement of all the systems optional. This capability became very important in the conduct of the Value Added Analysis, since the main emphasis was on identifying funding tradeoffs among the candidate systems. Without the performance enhancing modifications, the model would not have been as responsive as was necessary to provide the required analytical support.

8-4. RESULTS AND CONCLUSIONS

a. Methodology and Computer Resources. The methodology introduced in this chapter seems to do a good job of incorporating the learning curve effects on costing into the budget constraints of the Value Added Analysis acquisition strategy optimization. The introduction of this feature greatly increases the computational overhead associated with solving problems of this nature. As a result, implementation of this enhancement to acquisition strategy models requires significantly increased computing resources to obtain a solution.

b. Approximation. This methodology is an approximation, and checks are necessary to ensure the approximation is accurate enough. Experience has shown that the approximation has yielded results in which the expended program dollars, calculated using the nonlinear cost function and the optimized quantities, are within 2 percent of the nominal value. Considering the approximate nature of costing systems that will only be procured in the far distant future, 2 percent is adequate. In applications that require more accuracy, the approximation can be made more exact by increasing the number of pieces in the piecewise approximation.

c. Application. The use of this methodology has been shown to improve the quality of the optimization for the purpose of acquisition strategy. In this era of tightly constrained budgets for procurement, accurate costing is essential to get the most from limited funds. This methodology has enhanced analytical efforts that help accomplish this task. This optimization model was successfully used to assist the Army Staff in evaluating the various alternative weapon systems considered for procurement. The model was particularly useful in identifying the years in which budget constraints were extremely tight with respect to planned production campaigns, suggesting modifications that could be made to proposed programs. The model was also extremely useful in identifying systems that were excluded from the solution when other systems, or combinations of systems, were forced to be procured. This capability gave the leadership a window into the cost of their decisions as they related to system tradeoffs.

d. Conclusion. VALOR has provided a new dimension to the PPBES process for the Department of the Army Staff. The Staff now has available in a single model the capability to pull together data, policy, and guidance quickly and accurately in order to develop a balanced Army program.

CHAPTER 9

SUMMARY AND FINDINGS

9-1. INTRODUCTION. The purpose of this chapter is to provide the summary and findings for the Value Added Analysis (VAA) Phase II Study. Chapter 9 is structured as follows:

- Introduction
- Summary
- Observations and Findings
- Quick Reaction Analyses Completed
- Future Development

9-2. SUMMARY. The purpose of the VAA Phase II Study was to implement the VAA methodology as created and defined in the Phase I work. There has been partial success in implementing the Value Added methodology as originally envisioned. A primary objective of the VAA Phase II Study was to automate a large portion of the methodology for use by action officers in the Pentagon. The concept of action officers conducting a full-scale value added type analysis proved to be unrealistic as a result of the work completed in this study. The combat modeling, the structuring of costs, the formulating of the optimization, and the defining of issues requires a level of commitment that the action officers in the Pentagon cannot provide. The daily requirements of the action officer do not allow the time to conduct these types of analyses "in house." A major finding as a result of this issue is the need to have an analytical organization, such as the US Army Concepts Analysis Agency, involved in the process throughout the analysis period. Furthermore, this issue of time and resource availability points to a need to modify the architecture and data structure of the VAAC. The following paragraph provides specific observations and findings.

9-3. OBSERVATIONS AND FINDINGS

a. Essential Elements of Analysis Observations and Findings. The observations and findings contained in this paragraph are keyed to the EEA as listed in the study directive.

(1) EEA 1. What is the "value added" of a select number of major item systems to be considered in the 1994-1999 Program Objective Memorandum (POM)?

(a) The team initially started with a list of 119 systems for review as part of the VAA Phase II effort. This list was revised using a set of criteria which included the team's ability to model the system, the existence of a system requirements document, and the determination that the system represented a major acquisition in terms of the total dollars associated with the system's program. The first cut of the original 119, based on the previously mentioned criteria, resulted in a list of 50 major item systems. Each of the systems on this "first cut" list were modeled in CORBAN. As the team gained experience with particular systems and as decisions were made by the Army leadership, several systems were dropped from consideration. The final list consisted of 41 systems as shown in Figure 9-1 under the 2008 column.

(b) Figure 9-1 provides the "value added" of each of the systems by year (FY 96, FY 01, and FY 08) as a 1 to N list developed from the Effectiveness Integration Module. A word of caution is provided for the reader at this point. These numbers represent the combined effectiveness for both the Stressful and Contingency Scenarios and prior to their modification as per-system values. The values actually represent the effectiveness of the force as modeled in CORBAN. The number is a total for actual numbers played and not necessarily for the final optimized number of systems.

(2) EEA 2. What kind of characteristics should the VAAC have in order to implement the VAA methodology?

(a) As defined in the VAA Phase I Study, the VAAC was to be a set of models and tools residing on the METAPHOR computer architecture. The advantage of this arrangement as originally developed was that it would allow the action officer in the Pentagon to use the data base engine of METAPHOR to define and shape the issues to be studied. The action officer would then use the ability of METAPHOR to move in and out of the PC environment in order to run the VAA models and tools for conducting a value added analysis. CAA, PAED, and ODCSOPS Information Management Office (IMO) were able to obtain connectivity, and many of the tools and unique VAA data bases were placed in the METAPHOR environment. However, the ability to move in and out of the METAPHOR environment into the PC environment was found to be somewhat limited. This limitation, coupled with time and resource constraints associated with having action officers attempt to do these types of analyses, prohibited the implementation of the proposed VAAC design during the study period. As such, the VAA methodology as described provides the appropriate VAAC, but the actual work should be accomplished by an analytical organization such as CAA.

1996		2001		2008	
System name	Coefficient	System name	Coefficient	System name	Coefficient
WAM	.837	ADATS	.712	FIFV	.855
AAWS-M	.678	MLRS TGW	.637	RAH-66 LB	.653
ADV QUICKFIX	.578	M1A2	.615	RAH-66	.631
ADATS	.575	HAB	.536	AH-64 LB	.583
JSTARS	.492	RAH-66	.534	MLRS TGW	.498
AIR VOLCANO	.475	AH-64 LB	.527	ADATS	.493
ATAS	.454	GBS	.524	AFAS	.425
HAB	.442	WAM	.505	GBCS-L/H	.425
MLRS SADARM	.395	ATAS	.435	TOW2B	.416
PLS	.393	ADV FF	.388	HAB	.401
GBCS-L/H	.285	AVENGER	.388	AIR VOLCANO	.398
HET	.273	ATACMS II	.351	FMTV 5	.389
TOW2B	.269	ARV	.343	FMTV 2.5	.389
AVENGER	.266	155 ER	.339	GBS	.388
ARV	.258	155 TGP	.327	WAM	.387
M1A2	.247	NLOS-AT	.325	AAWS-M	.376
VEMASID	.242	155 LT WT	.324	HET	.368
GND VOLCANO	.211	HET	.315	STINGRAY	.352
FMTV 5	.182	GBCS-L/H	.307	JSTARS	.348
FMTV 2.5	.182	JSTARS	.301	155 LT WT	.347
		AMS-H	.272	FARV-A	.340
		AAWS-M	.262	155 TGP	.337
		TOW2B	.249	PLS	.336
		GND VOLCANO	.247	BLOCK III	.332
		STINGRAY	.245	VEMASID	.324
		PLS	.241	155 ER	.313
		LOSAT	.222	ADV QUICKFIX	.312
		ADV QUICKFIX	.220	AVENGER	.280
		FMTV 5	.217	M1A2	.277
		FMTV 2.5	.217	ADV FF	.273
		MLRS SADARM	.216	AMS-H	.271
		AIR VOLCANO	.202	ATACMS II	.269
		VEMASID	.189	MLRS SADARM	.262
		AGS	.017	GND VOLCANO	.238
				ADV SEMA	.235
				ARV	.212
				NLOS-AT	.211
				ATAS	.201
				LOSAT	.174
				AGS	.168
				CMV	.142

Figure 9-1. Value Added Analysis System List

(b) The team found that the action officers in the Pentagon were unable to find the time to learn either the METAPHOR computer software or the VAA tools. This constraint indicated to the VAA study team that the VAAC would have to be designed to facilitate the action officers having access to the input data, access to the issue definition narrative data, and then to the results of the Value Added Analysis. However, the Value Added Analysis would need to be conducted by an analytical organization outside of the HQDA ARSTAF or by a special study group. The need to have a separate study group and visibility/access for the action officers creates the requirement for the VAAC to be able to move easily from a data base environment into a decentralized computational environment and back again. The ability to pull data from the Army corporate data bases, format the data, and then move that data into the VAA tools and models must be well developed. The connectivity of data and tools must be enhanced over the manner in which this type of function was handled in VAA Phase II, which was the hand-carrying of data on floppies from one machine to another. The study group conducting the analysis should be able to move from the IBM RISC 6000 computer to the Macintosh computer and back to the data bases in a manner which is transparent to the analyst. Likewise, the action officer must be able to query the results of the study group work, the assumptions for the work, and the input data for the particular work.

(3) EEA 3. What kinds of tools, techniques, and models are needed to support the VAA methodology?

(a) The VAA Phase I effort investigated the idea of using spreadsheet costing tools, a simplified optimization, and the use of CORBAN for the combat modeling. Much of the work that was completed during Phase I was hand-generated, with little experience as to how data or processes might be connected. The major thrust of the VAA Phase II effort was to develop a more complete combat modeling capability, expand the optimization tool, implement the changes to TOPSIS recommended by the ORSA Center at the USMA, and take the analysis concepts and develop them into a full set of tools. The survey technique developed during VAA Phase I and the use of the analytical hierarchy process remained relatively unchanged. The only change associated with these last two techniques was the development of a different hierarchy. This was not a matter of change in technique as much as it was defining the context for the VAA Phase II effort. Essentially, the survey approach was the same in both phases.

(b) The first model improvement needed to support the VAA methodology included a combat model which was both easier to set up and faster in its run time than the stochastic CORBAN used in the Phase I study. The team looked at other models such as AFP, Eagle, and VIC as possible solutions. The team decided that AFP was at too aggregated a level, that Eagle was not yet developed enough to use, and that VIC was at too high a level of resolution. All of these models also had the same limitations as CORBAN in that they all have extensive setup requirements. This review of the combat models had the net effect of validating the need for CORBAN. However, the team determined that a full experimental design using stochastic CORBAN was not possible. Therefore, the team worked with TRADOC to obtain a deterministic version of CORBAN in an effort to speed up the run time. This change proved to be extremely important, because it allowed the team to perform excursions relatively rapidly. However, in order to develop values for all 41 systems, a very large experimental design was required. Even a deterministic CORBAN was not fast enough to accomplish all the runs required. The requirement to turn over many excursions for a wide range of weapon system mixes led to the use of an RSM. The VAA Phase II experience in using RSM was very favorable. The RSM technique

allowed the team to accomplish the development of values for all of the systems. RSM also had a side benefit of allowing the team to predict the explicit MOE values one would obtain by playing the weapon mix coming out of the optimization.

(c) A more fully developed optimization formulation was another technique/model needed to fully implement the VAA methodology. In VAA Phase I, a relatively simple formulation was used for the linear program in order to demonstrate the feasibility of the methodology. It was evident that any follow-on effort had a need for dynamic costing to accommodate the concept of system learning curves in order to provide a more accurate cost within the optimization. Phase II also identified the requirement to link certain systems together if they are dependent upon one another. For example, in the AFAS and FARV-A case, FARV-A is not procured unless AFAS is being procured. Finally, the capacity to continue to fully incorporate both force structure and production data was maintained, along with institution of better quality control on the data.

(d) VAA Phase I validated the concept of using a linear combination technique for integrating the effectiveness values. The TOPSIS technique used in Phase I was reviewed by the ORSA Center at USMA. Their suggestions for improvement were implemented in the Phase II Study.

(e) The cost analysis tools developed as part of this VAA Phase II effort have proven to be very useful to the sponsors. LCCM has been expanded and refined to include the ability to conduct "what ifs" on quantities and average unit costs. The tool has been transferred to HQDA PAED and is currently in use by PAED analysts. Further refinement, to include the development of generic LCCMs by mission area, would be useful in conducting analysis on developmental systems which currently do not have a BCE.

(4) EEA 4. What explicit effectiveness models are most appropriate for a Value Added Analysis Study (Value Added Analysis 1994-1999)?

(a) In VAA Phase I, the issue of using a highly aggregated combat model was addressed. The conclusion was that an aggregated model could provide useful insights for answering macro-level program tradeoff questions. However, it was also noted that decisionmakers require sufficient detail to understand the reasons for combat outcomes to assist them in specific program decisions. This point was reinforced in work completed as part of VAA Phase II. Almost universally, decisionmakers wanted to know the reasons behind the combat results. The use of RSM compounded the problem by not considering the effects of interaction and only looking at the first order effects. This tradeoff between detail and the ability to look at a large number of systems will continue to be an issue.

(b) It appears to the study team that for weapons systems' tradeoffs, the force-level model continues to be appropriate. However, the issue of interaction and need to explain results reinforces an idea from the Phase I Study regarding a hierarchy of models and MOE. The team was unable to explore this concept in any detail at this time. It is recommended that the idea of model/MOE hierarchy and how one would incorporate the RSM design into this hierarchy be research as part of a follow-on study.

(c) This particular EEA was aimed at a larger issue than just RDA appropriation modeling and the combat modeling associated with study weapon system tradeoffs. At the outset, VAA Phase II was starting to look at other appropriations such as OMA, MCA, and perhaps MPA. Although these appropriations were considered, especially in the LCCM costing, true tradeoffs were not conducted. The team did explore some preliminary tradeoffs in the area of OMA to RDA and MPA to RDA. This preliminary work suggests that additional explicit effectiveness models are required, such as Operational Tempo (OPTEMPO) models, training models, and the inclusion of campaign models. This, too, is an area which requires additional research as part of a follow-on study.

(5) **EEA 5. What refinements are needed to improve the VAA methodology?** Answers to the previous EEA suggest some areas for refinements. The work completed in the VAA Phase II effort has shown that the methodology works and can provide useful and timely support to decisionmakers. Additional work is needed to expand the use of the methodology into a broader range of issues. These include a variety of combat systems (e.g., logistics and command and control (C^2)) and other appropriations (e.g., OMA and MCA).

b. Other Observations and Findings. The observations and findings contained in this paragraph are not necessarily keyed to the original questions proposed in the study directive, but are insights obtained as a result of the work completed in this study.

(1) Input data intensity, accuracy, and timeliness continue to be of crucial importance in making the value added process operational.

(2) The need to have the survey process standardized was confirmed in this study.

(3) Issue definition is clearly an iterative process and should not be thought of as having a beginning or ending, *per se*.

(4) Future experimental designs should try to incorporate the need to investigate second order effects (i.e., synergism and weapon system interactions).

(5) Production data as depicted in the procurement (P-21) forms is not sufficient or timely enough to conduct Value Added Analysis on an institutionalized basis. The production data required for Value Added Analysis (as well as for other acquisition analyses conducted for HQDA) should be made readily available and current in support of budgetary decisionmaking.

(6) Standardized cost codes and views as implemented in the VAA Phase II Value Added Analysis Study should be used throughout the Army. The Life Cycle Cost Model should be made available to program executive offices (PEOs)/PMs and help form the basis for standardization.

(7) Major item system data as defined in the Army Resource Integration and Management (ARIM) Study should be institutionalized and used throughout to assist in standardization of costs and system definition.

9-4. QUICK REACTION ANALYSES (QRAs) COMPLETED

a. The VAA Phase II study directive stated that the primary purpose of the study was to implement the VAA methodology. The VAA Phase II Study in fact refined the methodology as developed in the Phase I Study and built tools to implement the method. In addition to building these tools, the team also completed the work and analysis necessary to produce VAA Coefficients for 41 systems. This might have been considered the end of the study and that all objectives had been met. However, it was clear to the team that this did not constitute analysis or implementation of the method as originally intended (as a tradeoff tool to conduct cost/benefit analysis). Even in the development of the study plan for the VAA Phase II Study, there was a block which was called POM support. The intent of the team was to assist the sponsor in conducting some type of Value Added Analysis in support of the POM. This opportunity came in the form of the LRRDAP Review. The team was asked to assist in the review of the LRRDAP by conducting VAA tradeoff analysis in order to fit the plan into the current OSD fiscal (POM) guidance. The team did conduct a preliminary analysis which was presented to the DA Council of Colonels, which consisted of representatives from both the study sponsors and the Office of the Assistant Secretary of the Army for Research, Development, and Acquisition (ASA(RDA)). This work was expanded by the Council into a series of QRAs which culminated in a briefing to the Chief Staff of the Army (CSA) Offsite Review for the LRRDAP. Table 9-1 provides a list of the QRAs conducted in support of the CSA Offsite. Two additional QRAs were conducted in support of the Army Select Committee (SELCOM) and the Secretary of the Army. However, for the purpose of demonstrating the implementation of the Value Added Methodology, the work completed in support of the Chief of Staff Offsite appears to be the most appropriate.

Table 9-1. Value Added Analysis QRAs in Support of CSA

QRA tasking	Sponsor	CAA document number
Comparison of LRAMRP and LRRDAP 2.0	DAMO-FD/ASPAD PAED/SARD-RI	CAA-MR-92-29
LRRDAP 3.0 General Office Review	DAMO-FD/ASPAD PAED/SARD-RI	CAA-MR-92-24
Aviation and Modernization Program Baseline	ASPAD PAED	CAA-MR-92-29
LRRDAP 3.1 Chief of Staff Offsite	DAMO-FD	CAA-MR-92-25
LRRDAP 3.1 Modified Chief of Staff Offsite (President's State of the Union Adjustments)	DAMO-FD	CAA-MR-92-25

b. Although five QRAs were conducted in support of the CSA Offsite and represent separate studies, the Modified Chief of Staff Offsite QRA was chosen for partial enclosure in this paragraph. The team felt that providing a description of the analysis and some examples of the products provided would be useful in helping the reader in understanding the implementation of VAA. The following provides some of the highlights from the Chief Staff Offsite QRA.

(1) **Purpose.** The purpose of the CSA Offsite QRA was to assist the ARSTAF in allocating resources for modernization programs by assessing the relative contribution ("value added") of selected major item systems (VAA systems) from the LRRDAP 3.1 file.

(2) **Scope.** Using the appropriate baseline dollar resources (TOA) and forces, the analysis examines the relative worth of the VAA systems and provides an optimal mix of for the VAA systems. The following assumptions and limitations were used in the analysis:

- All costs and TOA are in current dollars.
- Production campaigns are fixed.
- Length of campaign is based on force structure requirements and production capability.
- Used LRRDAP 3.1 campaigns matching as closely as possible.
- Constrained to Force Package I or MSR, whichever is higher.

• Constrained to appropriate percentage of TOA based on the ratio of dollars allocated to the VAA systems in the LRRDAP 3.1 file. Figure 9-2 compares the various TOA levels for VAA systems over the previous analyses.

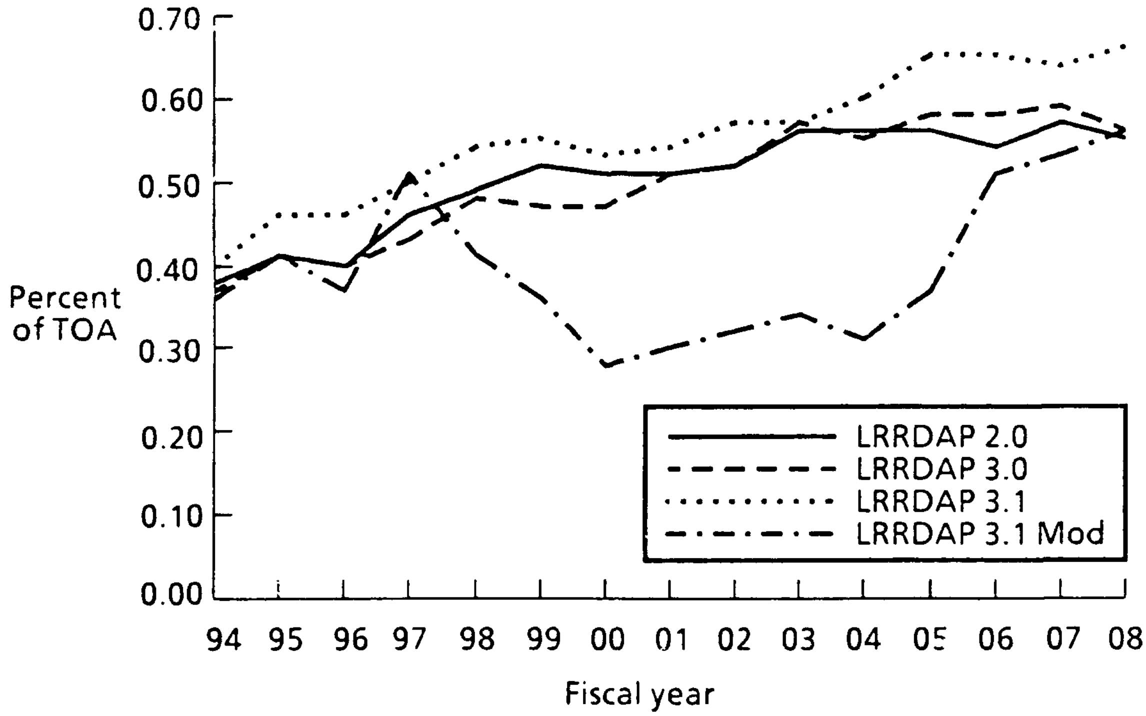


Figure 9-2. Comparison of Proportion of TOA for VAA Systems

• ASM program costs reflected the latest program restructuring.

(3) **General Observations.** The following observations have been drawn from the series of analyses that have been conducted to support the Modernization Review. They have consistently appeared in the observations of individual analyses.

• RAH-66 Comanche with LONGBOW is too expensive for procurement at the levels of funding considered in these analyses, in spite of a large contribution to force performance.

• Although separate procurement was an option, RAH-66 Comanche was always procured with the LONGBOW, when it was forced into a solution.

• The following systems appeared to be "fillers;" that is, they are recommended only when there is enough TOA left to fund them. They are systems that are frequently traded off.

•• MLRS SADARM.

•• Nonline of sight-combined arms (NLOS-CA).

•• Amored recovery vehicle (ARV).

- M1A2 Abrams main battle tank and Block III tank have never been recommended.

- The relatively high cost of both common chassis RDTE and lead ASM system procurement (AFAS) force the ASM program out of the set of systems recommended by VAA.

Figure 9-3 shows commonalities and differences between LRRDAP 3.1 and VAA.

Included in VAA	Included in both	Included in LRRDAP
Advanced Firefinder	AAWS-M	AFAS
AH-64 Apache w/ LONGBOW	AGS	Block III tank
AMS-H	Advanced QUICKFIX	FARV-A
ATACMS II	ARV	FIFV
155mm LtWt How	Avenger	LOSAT
NLOS-CA	FMTV	RAH-66 Comanche
STINGRAY	GBCS-L/H	RAH-66 Comanche w/LONGBOW
	GBS	SADARM
	JSTARS	
	PLS	
	SADARM (MLRS)	
	TOW 2B	
	VOLCANO	
	WAM	

Neither VAA nor LRRDAP recommended these systems:

ADATS
CMV
M1A2

Figure 9-3. VAA - LRRDAP 3.1 Comparison

(4) **Description of Modified Baseline.** The following is a description of the modified baseline used to support the Chief of Staff Offsite:

- Systems were allowed to buy into Force Package II.

- The following systems were not considered:

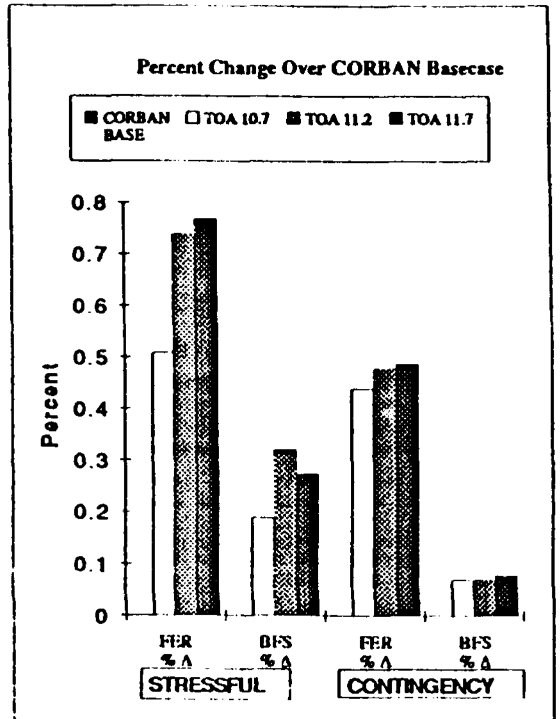
  - ATAS, 155mm field artillery extended range (155 ER), 155mm terminally guided projectile (155 TGP), MLRS-TGW, advanced special electronic mission aircraft (ADV SEMA), vehicle magnetic signal duplicator (VEMASID), heavy assault bridge (HAB), and heavy equipment transporter (HET).

- The following systems were considered in the excursions:
  - Air Defense Antitank System (ADATS), line of sight antitank (LOSAT), and RAH-66 Comanche with and without LONGBOW.
- Each level of TOA was evaluated as a separate "optimization."
- TOA includes a 3.2 percent growth for inflation in the EPP years.
- Only three levels of TOA were considered--$10.7, $11.2, and $11.7 Billion.
- ASM systems linked to AFAS:
  - FARV-A must be procured with AFAS.
  - All other ASM systems were restricted from procurement unless AFAS is procured.
- Army Tactical Missile System Block II (ATACMS II) costs and quantities were directly obtained from LRRDAP 3.1 file.
- Armored Gun System (AGS) forced to be procured.
- Advanced Missile System-Heavy (AMS-H) program delayed 2 years.

(5) **Modified Baseline Observations.** Figure 9-4 provides a typical example of the output from a VAA QRA. The following is a description of the modified baseline observations:

- FY 00 was no longer the bottleneck year, restricting buys in all three TOA levels.
- No ASM systems were recommended.
- The primary tradeoff was between NLOS-CA at $10.7 billion level and ATACMS II at higher TOA levels.
- At the $10.7 billion level, ATACMS II, and SADARM were recommended vice ARV.
- At the $11.2 billion level, the family of medium tactical vehicles 2.5/5-ton (FMTV 2.5/5) and AH-64 Apache with LONGBOW were recommended.
- At the $11.7 billion level, FMTV and AH-64 Apache with LONGBOW, and NLOS-CA were recommended.

	VAA Systems By BOS		Level I $10.7	Level I $11.2	Level I $11.7
ADA	ADATS	Air Defense, Anti-Tank System			
	Avenger	LOS Rear/Fwd Mid Stinger	x	x	x
	GBS	ADA Ground Based Sensor	x	x	x
AMM	WAM	Wide Area Mine	x	x	x
CSS	FMTVS	Family of Med Tac Veh (5-Ton Truck)	x	x	x
	PLS	Palletized Loading Sys (Heavy Truck)	x	x	x
	FLTV	Family of Light Tac Veh (HMMWV)			
	FMTV2.5	Family of Med Tac Veh (2 1/2 Ton Truck)	x	x	x
FS	SADARM	Sense & Destroy Armor MLRS	x		
	155LTWGT	Light Weight 155 Howitzer	x	x	x
	ADVFF	Advance Firefinder	x	x	x
	ATACMS2	Army Tactical Missile Sys Blk II	x	x	x
	AFAS	Adv FA System			
	FARV-A	Future Armd Resupply Veh-Artillery			
IEW	Adv QUICKFIX	Adv QUICKFIX/Aerial Com Snsr Div	x	x	x
	GBCS-L/H	Gnd Based Common Sensor (LIGHT/HVY)	x	x	x
	JSTARS	Joint Surv and Attack Radar System	x	x	x
MAN	AAWS-M	Adv Anti-Armor Wpn Sys-Med	x	x	x
	ARV	Armored/Improved Recovery Vehicle		x	x
	M1A2	Main Battle Tank			
	TOW 2B	TOW II Anti-Tank Missile	x	x	x
	AGS	Armored Gun System	x	x	x
	AH64LB	AH-64C Longbow Apache		x	x
	AMS-H	Adv Missile Sys-Heavy	x	x	x
	LOSAT	Line of Sight Anti-Tank			
	NLOS-CA	Non-Line of Sight-Combined Arms	x		x
	RAH-66	Reconnaissance & Attack Helicopter			
	STINGRAY	Combat Protection Device (Laser)	x	x	x
	BLOCK III	Block III Main Battle Tank			
	FIFV	Future Infantry Fighting Vehicle			
	RAH-66/LB	Recon & Attack Helo w/Longbow			
MOB	Vol Air	VOLCANO mines delivered by UH-60	x	x	x
	Vol Grd	Multiple Mine Deliver Sys - Ground	x	x	x
	CMV	Combat Mobility Veh			



NOTES:

1. An X in a column indicates whether a VAA System is procured at that level of TOA.

2. The table at the right displays the warfighting contribution of each mix of VAA systems as indicated by the "Xs" in a particular column.

3. Fractional Exchange Ratio (FER) is a measure of lethality and is the percent red losses divided by the percent blue losses.

4. Blue Force Surviving (BFS) is the percent of strength in remaining blue battlions.

Baseline

Measurement of Improved Force Performance

	STRESSFUL SCENARIO				CONTINGENCY SCENARIO			
	FER	% Δ	BFS	% Δ	FER	% Δ	BFS	% Δ
CORBAN BASECASE (Combat)	0.69		0.45		2.84		0.83	
VAA System Mix @ TOA 10.7	1.04	51%	0.54	19%	4.09	44%	0.88	7%
VAA System Mix @ TOA 11.2	1.20	74%	0.60	33%	4.20	48%	0.89	7%
VAA System Mix @ TOA 11.7	1.22	77%	0.58	28%	4.24	49%	0.89	8%

Figure 9-4. Chief of Staff Offsite Modified Baseline

9-5. VAA FUTURE DEVELOPMENT

a. Methodology. The study team believes the following methodological improvements or research should be conducted to enhance the VAA capability.

(1) There should be follow-on research to establish a hierarchy of MOE to evaluate a broader range of systems in the RDA accounts. The next iteration should include all of the Defense Acquisition Board (DAB) and Active Component (AC) systems plus additional systems from the current list of Army acquisition programs to capture at least 65 percent of the total dollars associated with the RDA appropriation. By way of comparison, the VAA Phase II systems captured from 39 percent to 57 percent of the total RDA TOA.

(2) An effort should be made to refine the current models and techniques, especially the optimization and multiattribute utility model, for developing the single measure of benefit should be undertaken.

(3) A test case should be developed to determine the requirement for VAA capability in other appropriations such as OMA, MPA, or MCA. If a requirement for expansion exists, then work should be conducted to identify or develop appropriate models for evaluating other appropriations. Also, the survey process should be redesigned to incorporate the need to do multiple appropriations.

(4) Analysis should be conducted to determine if a requirement for an across-appropriation balancing within the VAA context exists. If a requirement exists, then the following tasks should be completed:

(a) Articulate the current process.

(b) Translate the current process into the VAA context (start point).

(c) Identify ways of "improving" the process by applying analytical techniques.

(d) Frame a feasible methodology.

b. Implementation. The study team believes the following implementation issues should be addressed in follow-on work.

(1) Work should be completed to determine the extent to which VAA capability needs to be implemented in the METAPHOR environment.

(2) Another possible task for a follow-on study is to determine if useful data for VAA analysis can be developed using the METAPHOR and the corporate Army data bases currently available.

(3) An effort should be made to implement the resource allocation module.

(4) To successfully implement the VAA methodology, there is a need to create real connectivity for all users of VAA, both in terms of hardware and software.

APPENDIX A

STUDY CONTRIBUTORS

1. STUDY TEAM

a. Study Director

LTC Robert R. Koury, Force Systems Directorate

b. Team Members

COL John B. Harrington
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CPT Stephen E. McGuire
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Mr. Joel S. Gordon
Ms. Linda C. LaBarbera
Mr. Richard G. Poulos
Mr. Ronald P. Reale
Mr. Steven B. Siegel

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COL Robert Clark, PAED
COL Richard Engle, SARD
LTC Michael Pollster, DCSOPS
LTC James Richman, PAED
MAJ William Carlton, PAED

2. PRODUCT REVIEW BOARD

Mr. Ronald J. Iekel, Chairman
LTC Jerry B. Edelen
Mr. Louis J. Albert

APPENDIX B

STUDY DIRECTIVE

DEPARTMENT OF THE ARMY

REPLY TO ATTENTION OF:

DACS-DPZ

MEMORANDUM FOR DIRECTOR, U.S. ARMY CONCEPTS ANALYSIS AGENCY, 8120 WOODMONT AVENUE, BETHESDA, MARYLAND 20814-2797

SUBJECT: Army Program Value Added Analysis - Phase II (VAA 94-99).

1. PURPOSE OF STUDY DIRECTIVE: This directive establishes objectives and provides guidance for the conduct of the Value Added Analysis - Phase II Study.

2. BACKGROUND: Headquarters, Department of the Army (HQDA) needs analysis to support the development of a balanced and effective Army Program within Department of Defense resource guidance. The Army requires a methodology for identifying and comparing the warfighting contribution of major item systems proposed for research, development and acquisition during the time period of the Program Objective Memorandum (POM). The Value Added Analysis Methodology developed by U.S. Army Concepts Analysis Agency (CAA) during the Value Added Analysis - Phase I Study uses a hierarchical assessment framework for assessing return on investment as it relates to explicit and implicit measures of benefit when compared with cost.

3. STUDY SPONSORS AND SPONSOR'S STUDY DIRECTOR:

a. The Director, Program Analysis and Evaluation (DPAE), Office of the Chief of Staff Army, is a co-sponsor.

b. The Assistant Deputy Chief of Staff for Operations and Plans, Force Development (ADCSOPS-FD) is a co-sponsor.

c. The PA&E Study Sponsor's Representative is LTC James N. Richmann, (DACS-DPZ). The DAMO-FD Study Sponsor's Representative is COL Roger A. Brown, (DAMO-FD).

4. STUDY AGENCY: U.S. Army Concepts Analysis Agency.

5. TERMS OF REFERENCE:

a. Purpose. The purpose of this study is to assist the Army Staff (ARSTAF) in allocating resources for modernization programs by assessing the relative contribution ("value added") of major item systems toward the capability of US Army forces.

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b. Definitions.

(1) Value Added - refers to the marginal return on investment as measured using explicit effectiveness values and implicit effectiveness values as compared to cost.

(2) Major Item System - is a combination of major items,separately authorized secondary items, component major items, associated items of equipment, spare and repair parts, munitions, personnel and facilities that are jointly used to accomplish a specific function.

c. Scope.

(1) Baseline program is President's Budget FY 1992 and U.S. Program Force (FY 1995).

(2) The analysis will examine the RDA appropriations and other related appropriations as needed to investigate the full programing of selected major item systems.

(3) About 50 Major Item Systems (see enclosure 1) based on the following selection criteria: systems without a Mission Needs Statement (MNS) or other requirements document (such as a Required Operational Capability (ROC)) as of 1 October 1991 will not be included, systems with large dollar amounts in current and proposed programs will be included, and finally inclusion of a system is subject to our ability to execute in terms of data and modeling availability.

(4) Scenario Conditions: NATO Central Europe, Post-CFE, Defense; SWA Defense with Counter Attack; NEA Counter-Offensive; Consistent with TRADOC scenario(s).

(5) U.S. Army conventional operations capabilities will be assessed in terms of force packages, major item systems programmed for acquisition, and anticipated threat as of the end of FY 1996, FY 2001, and FY 2004.

(6) Conflict Type: Conventional

d. Objectives.

(1) To determine VAA coefficients and feasible acquisition alternatives for major item systems proposed by the Headquarters, Department of the Army Long Range Research Development Acquisition Plan (HQDA LRRDAP) and constrained by Modernization Total Obligation Authority (TOA). The process must measure and analyze the capability of US Army forces to

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SUBJECT: Army Program Value Added Analysis - Phase II (VAA 94-99).

conduct conventional operations in scenarios consistent with the Illustrative Planning Scenarios of the Defense Planning Guidance FY 1994-1999.

(2) To identify and develop a Value Added Analysis Capability (VAAC) to include all appropriate hardware, software, and interfaces. The VAAC must tap major authoritative Army data bases such as the Total Army Equipment Distribution Program (TAEDP), Force Accounting System (FAS), and The Army Force Cost System (TAFCS).

(3) To identify or develop models and techniques that support the VAA Methodology. The VAAC and related models must be capable of operating in a "quick turnaround" environment, defined as 1 week or less.

(4) To conduct a demonstration of the refined methodology and VAAC prior to the building of the 1994-1999 POM.

(5) To continue the refinement and implementation of the VAA Methodology for estimating the value added of either competing major item systems or Management Decision Packages (MDEPs) to the Total Army Program.

e. Timeframes.

(1) Fiscal obligation analysis timeframe: FY 1994, FY 1999, and FY 2006.

(2) Fielding analysis timeframe: FY 1996, FY 2001, and FY 2008.

(3) Combat analysis timeframe: Blue forces FY 1995 and Red forces FY 1996, FY 2001, and FY 2004 (Blue force is equal to FY 1995 basecase year which represent forces on hand as the result of the President's FY 1992 budget).

f. Limitations. The VAAC will initially be installed at CAA because the hardware and software required is currently available only at CAA.

g. Assumptions.

(1) The President's FY 1992 Budget position will be used for both the Program Optimization and Budget Evaluation (PROBE) and Research Development and Acquisition Information System Agency (RDAISA) databases.

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(2) The data survey results are assumed to reflect decision maker positions and provide a means of modeling the effect of the senior Army leadership on the Army decision making process.

(3) The measure of effectiveness (MOE) selected measures the utility of a major item system.

(4) There is a two year lag from expenditures of procurement dollars to item fielding.

h. Essential Elements of Analysis (EEA).

(1) What is the "value added" of a select number of major item systems to be considered in the 1994-1999 POM?

(2) What kind of characteristics should the VAAC have in order to implement the VAA Methodology?

(3) What kinds of tools, techniques and models are needed to support the VAA Methodology?

(4) What explicit effectiveness models are most appropriate for a Value Added Analysis Study (Value Added Analysis 1994-1999)?

(5) What refinements are needed to improve the VAA Methodology?

6. RESPONSIBILITIES.

a. D,PA&E will:

(1) Provide a study sponsor representative and study guidance.

(2) Provide a study team member.

(3) Provide support to the analysis for data required to conduct the VAA study.

b. ADCSOPS-FD will:

(1) Provide a study sponsor representative and study guidance.

(2) Provide a study team member.

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SUBJECT: Army Program Value Added Analysis - Phase II (VAA 94-99).

(3) Provide support to the analysis for data required to conduct the VAA study.

c. CAA will:

(1) Conduct the Value Added Analysis Study.

(2) Designate a study director and provide the study team.

(3) Coordinate/communicate with the PAED, ODCSOPS, TRAC, CEAC, ASARDA, AMC and others for data and information to accomplish the study.

(4) Provide periodic in-process reviews (IPRs) as requested by the study sponsors.

7. REFERENCE. The draft Value Added Phase I Report provides the basis for the methodology and approach to Phase II. Other references include the President's FY 1991 Budget and CAA's Army Resource Integration and Management Study.

8. ADMINISTRATION:

a. Support.

(1) Funds for travel/per diem will be provided by the parent organizations of the individuals traveling.

(2) ADP support will be provided by CAA.

(3) Secretarial support, reports, and publication will be provided by CAA.

(4) ODCSOPS will provide access to and use of the METAPHOR Computer.

b. Milestone Schedule.

(1) Key milestone dates.

Initial SAG	~~4 June 1991~~ tbd
Refinement of Methodology Completed	16 July 1991
SAG Review of Weights and SIAM Factors	1 July 1991
VAAC Complete / Software Testing Begins	25 July 1991
Analyze Results of Demonstration	12 August 1991
POM Support Prep Complete	1 October 1991
Support POM Development	4 November 1991

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Final SAG	28 February 1992
VAA Phase II Ends	27 March 1992

(2) A complete schedule is at enclosure 2.

c. Control Procedure. The study sponsors' representatives will coordinate/communicate within the HQDA staff and between the ARSTAF and the study agency.

2 Encls

JEROME H. GRANRUD
Major General, USA
Assistant Deputy Chief of Staff for Operations and Plan, Force Development

THOMAS P. CARNEY
Major General, USA
Director, Program Analysis and Evaluation

	SHORT NAME	NOMENCLATURE	CAA
1	AH-1 G/S	Cobra Attack Helo	BC
2	AH-64	Apache	BC
3	ATACMS I	Army Tactical Missile Sys Blk I	BC
4	BFV	Bradley Fighting Vehicle	BC
5	CHAPPARRAL	Chapparral	BC
6	FAASV	FA Ammo Supply Vehicle	BC
7	GR/CS	Guardrail/Comm Snsr-Corps	BC
8	HAWK	HAWK	BC
9	HTARS	HEMTT Tanker Aviation Refueling	BC
10	M1	Abrams Tank 105mm	BC
11	M109	155mm Howitzer SP	BC
12	M110A2 8"	8" Howitzer	BC
13	M119 105mm h.	M119 105mm How	BC
14	M163	Vulcan ADA Gun	BC
15	M1A1	Abrams Tank 120mm	BC
16	M9 ACE	M9 Armored Combat Earthmover	BC
17	MLRS	Mulitple Launch Rocket System	BC
18	OBV	Obstacle Breeching Sys (M1)	BC
19	OH-58D	Army Helo Imp Pgm	BC
20	STINGER	STINGER	BC
21	HET	Heavy Equipment Transport	BC/I
22	SADARM MLRS	Sense & Destroy Armor MLRS	BC/I
23	TOW 2A/2B	TOW II AT Msl	BC/I
24	AAWS-M	Adv Anti-Armor Wpn Sys-Med	I
25	ADATS	Line of Sight Fwd, Heavy	I
26	AEI	Armanent Enhancement Initiative(Ammo)	I
27	AFAS	Adv FA System (ASM)	I
28	AGS	Armored Gun System	I
29	AH-64 LB	AH-64C Longbow Apache	I
30	AMS-H	Adv Missile Sys-Heavy	I
31	ATACMS II	Army Tactical Missile Sys Blk II	I
32	ATAS	Air-to-Air STINGER	I
33	AVENGER AGS	Los Rear/Fed Mtd STINGER	I
34	Adv QUICKFIX	Adv QUICKFIX/Aerial Com Snsr Div	I
35	BLOCK III	Block III Main Battle Tank	I
36	CMV	Combat Mobility Veh Next Generation	I
37	FIFV	Future Infantry Fighting Vehicle	I
38	HIP (M109A6)	Howitzer Improvement Program	I
39	JSTARS	Joint Surv and Attack Radar System	I
40	LH w/LONGBOW	Light Helo w/Longbow	I
41	LH	Light Helicopter	I
42	LOSAT	Line of Sight Anti-Tank	I
43	Lt Wgt 155 How	Light Weight 155 Howitser	I
44	M1A2	Tank	I
45	MLRS TGW	MLRS Terminally Guided Warhead	I

	SHORT NAME	NOMENCLATURE	CAA
46	NLOS-AT	Non Line of Sight -Anti-Tank	1
47	PATRIOT	PATRIOT System Growth	1
48	WAM	Wide Area Mine	1
49	155 FAER	155 FAER (EXTENDED RANGE)	2
50	155 TGP	155 Terminally Guided Projectile	2
51	AH-64 Imp	Apache Improvements	2
52	ARV	Armored Recovery Vehicle	2
53	Adv SEMA	Adv Special Elec Msn A/C	2
54	Advance Firefinder	Advance Firefinder	2
55	Air VOLCANO	Subsystem of VOLCANO for UH-60	2
56	CORPSAM	Corps Surface-to-Air Msl Sys	2
57	FARV-A	Future Armd Resupply Veh (ASM)	2
58	FLTV	Family of Light Tac Veh (HUMVEE)	2
59	FMTV	Family of Med Tac Veh (5-Ton TRK)	2
60	Firefinder Block II	Firefinder Block II	2
61	GBCS-L/H	Gnd Based Common Sensor (LIGHT/HVY)	2
62	GBS	Ground Based Sensor	2
63	GLTR	Gnd Lchd Taoit Rainbow	2
64	HAB	Heavy Assault Bridge (M1 AVLB)	2
65	MPIM	Multipurpose Ind Munition (AT Wpn)	2
66	PLS	Palletised Loading Sys	2
67	STINGRAY	Combat Protection Device	2
68	VEMASID	Vehicle Magnetic Sig Duplicator	2
69	VOLCANO	Multiple Mine Deliver Sys	2
70	ADDS	Army Data Distribution Sys	3
71	AFATDS	Adv FA Tactical Data Sys	3
72	AGSM	Army Grnd Station/Comm Gnd System	3
73	AMV	Armored Maint Veh	3
74	APOBS	Antipers Obs Breaching System	3
75	ASAS	All Source Analysis Set	3
76	ATCSS Common H/S	ATCSS Common Hardware/Software	3
77	ATLAS	All Terrain Lift Articulated Sys	3
78	CCTT (NSTD)	Close Combat Tactical Trainer	3
79	CSSCS	Cbt Ser Spt Control Sys	3
80	CTT	Cmdr's Tactical Term/CTT Hybrid	3
81	FAAD C2I	Fwd Air Def Command and Control	3
82	FAAPC	FA Ammo Processing Center	3
83	FAAV	Future Attack Aerial Vehicle	3
84	FED	Forward Entry Device	3
85	FRV	Future Recovery Vehicle	3
86	FSV	Fire Support Vehicle	3
87	HAWK Sweepdown	HAWK Sweepdown	3
88	HIMAD Radar	High/Intermed Air Defense Radar	3
89	HIMARS	High Mob Arty Rkt Sys	3
90	IFTE	Integrated Family of Test Eq	3

	SHORT NAME	NOMENCLATURE	CAA
91	IHFR Upgrade	Imp HF Radio Upgrade	3
92	IMETS	Integrated Met Sys (Weather)	3
93	LAMP-H	Lighter, Amphibian Heavy Lift 60T	3
94	LH/P3I	Light Helo's Product Improvements	3
95	M109A5 MOD	M109A5 MOD	3
96	M198 MOD	155mm How/Imp Armament Sys	3
97	MCS	Manuever Control System	3
98	MLAW	Manportable Laser Assault Weapon	3
99	MSE Enhancements	Mobile Subs Eq Enhancements	3
100	MTV-LE	Med Tact Veh Life Extension	3
101	Mine Detection	Detection Set, Mine	3
102	Multi-Option Fuse	Multi-Option Fuse Artillery	3
103	NBC Detect	NBC Detect, ID, & Warning	3
104	PATRIOT Sweepdown	PATRIOT Sweepdown	3
105	RCVR Tech	Communications ECM AD/ED	3
106	SINCGARS	Combat Net Radios	3
107	STAMIDS	Standoff Minefield Detection Sys	3
108	Soldier System	Clothing and Individual Equipment	3
109	TENCAP-ELECT	Tactical Ex on Natl' Capabilities-E	3
110	TENCAP-IMIT	Tactical Ex on Natl' Capabilities-I	3
111	ATMD	Active Tactical Msl Defense	4
112	UAV-CR	Unmanned Aerial Veh Close Rg	4
113	UAV-Endure	Unmanned Aerial Veh Endurance	4
114	UAV-SR	Unmanned Aerial Veh Short Rg	4

CRITERION:

1 THE SYSTEM HAS A REQUIREMENTS DOCUMENT HIGHER THAN AN O&O, HAS A LARGE M
HAS GIVEN THE ITEM AS A "1" PRI, AND HAS AVAILABLE DATA THAT CAN BE MO

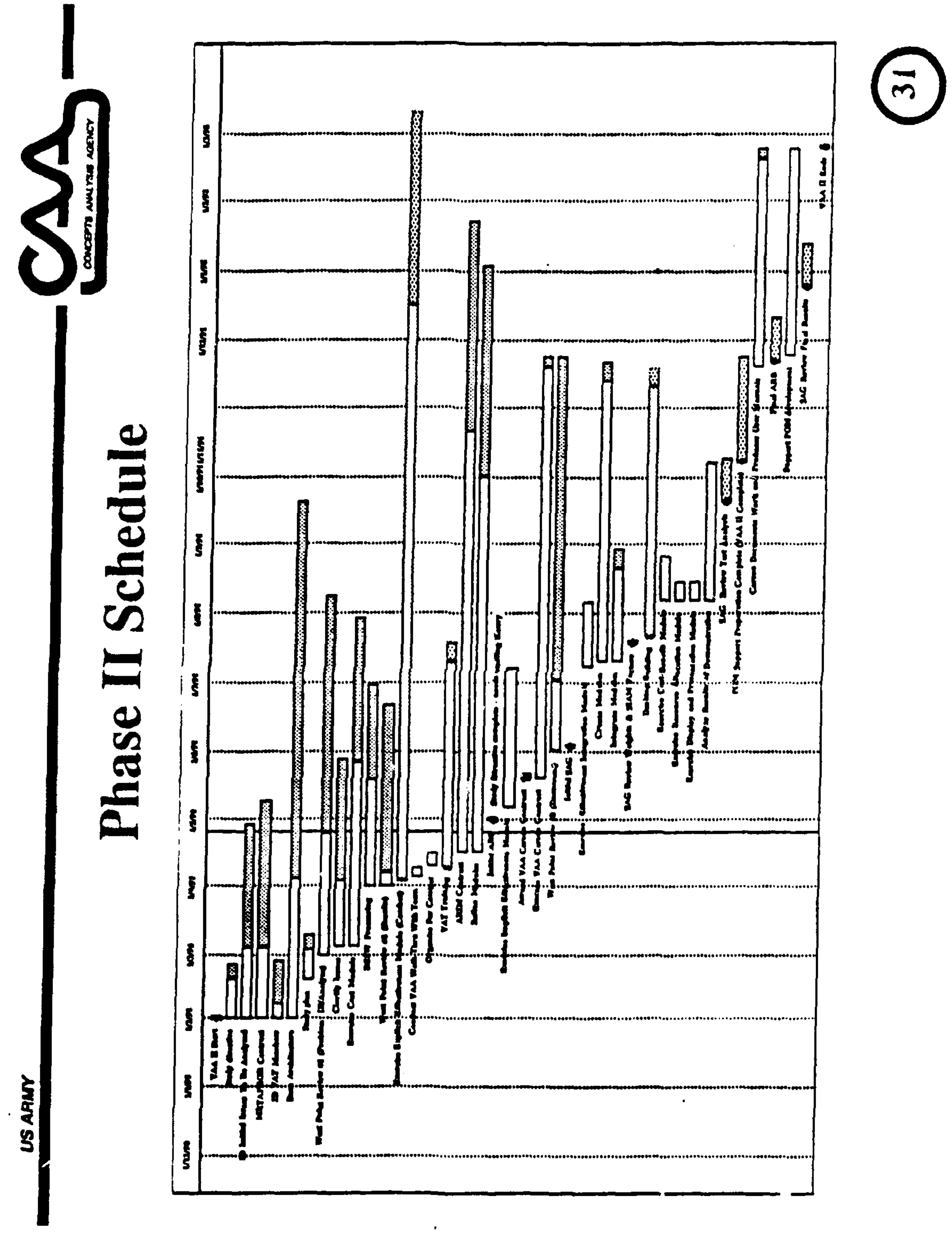
2 SYSTEM IS AN ISSUE AND MAY BE ABLE TO BE MODELED

3 THE SYSTEM HAS A LOW PRIORITY FROM ODCSOPS & PA&E, HAS A LOW DOLLAR AMOU

4 SYSTEMS THAT WILL NO LONGER BE CONSIDERED

BASE SYSTEM OR IOC 95:

1. FIELDED AS OF 1995
2. NOT AN ISSUE FOR ADDITIONAL FUNDING



Encl 2

APPENDIX C

BIBLIOGRAPHY

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APPENDIX D

DECISIONMAKER SURVEY MEMORANDUMS

Presented in this appendix are the memorandums identifying decisionmaker surveyees and providing information regarding background and conduct of the survey.

CSCA-FSR

1 August 1991

MEMORANDUM THRU Mr. Steve Siegel, FSR
COL Harrington, FS

FOR Director, Concepts Analysis Agency

SUBJECT: Identification of VAA Decision Maker Surveyees

1. Reference:

a. FONECON, LTC Richmann, DACS-DP; LTC Koury, CSCA-FSR; and MAJ Clayton, CSCA-FSR at 221300JUL91.

b. Meeting, 29JUL91, LTC Richmann, DACS-DP; LTC Pollster, DAMO-FDR; and LTC Koury, CSCA-FSR, at the Pentagon.

2. The following individuals were tentatively identified as target surveyees for the conduct of Value Added Analysis (VAA) Phase II:

ASA(RDA)
DUSA(OR)
Deputy ASA (Plans and Programs)
Military Deputy to the ASA(RDA)
Comptroller of the Army
DCSOPS
DCSLOG
DISC4
DAS
DCSPER
DCSINT
Director, PAED
ADCSOPS (Force Development)
Director, CAA
Chief, Army Reserve
Chief, National Guard Bureau
Chief of Engineers
DCSRM, FORSCOM
DSCRM, TRADOC
DCSCD, TRADOC
DCSRM, AMC
DCS(Development, Engineering, and Acquisition), AMC
DCSRM, Health Services Command
DCSRM, USAREUR
DCSRM, WESTCOM

3. VAA sponsors have initially approved the list above. Another list of subject matter experts for the scoring of the secondary factors will be provided at a future date.

4. POC, this action, MAJ Clayton, CSCA-FSR, (301)295-5291/0211.

ROBERT R. KOURY
LTC, IN
Study Director

CF: LTC Richmann, DACS-DP
LTC Pollster, DAMO-FDR

CSCA-FSR 22 August 1991

MEMORANDUM FOR VAA DECISION MAKER SURVEYEES

SUBJECT: VAA DECISION MAKER SURVEY READ-AHEAD PACKAGE

1. Purpose. This memo will provide information on the background and conduct of the Value Added Analysis (VAA) Decision Maker Briefing and Survey

2. Problem. The Army requires the capability to systematically & efficiently evaluate the relative contribution ("Value Added") of Major Item Systems toward the capability of US Army forces.

3. General. Value Added Analysis is the self-refining procedure developed to provide a value of relative contribution for systems under consideration in the upcoming POM. Divided into effectiveness and cost arenas, VAA uses existing operations research and management techniques. It combines the macro perspective input from decision makers, to derive weighted criteria, with the system/program specific input of technical experts, simulation results, and cost estimations. In combination, the information and algorithms are put into an automated environment where real-time evaluation is made available to those integral to POM development.

4. Chronology. The current phase of VAA (II) was initiated in May 1991 with a signed study directive. Surveys are to be completed by mid-September. Final demonstration, in line with POM 94-99 development, is to be completed by OCT 91.

5. Surveys. The startpoint and direction of the effort lies with the input of decision makers who are polled, via pairwise comparison techniques, on respective weights of timeframes-scenarios, implicit (unquantifiable) factors affecting programs, and measures of effectiveness. Additionally, a system by system comparison is done in a survey of technical experts to determine the relative potential of each system in each of the implicit factors. All surveys are non-attributable and information is handled as close hold by the VAA team.

6. Conduct of Decision Maker Surveys. Designed to be completed in a 30 minute period, the session begins with a briefing of VAA, followed by an example, and then with the actual surveys. Each of the four surveys is introduced by purpose, necessary definitions, and conventions. The survey instruments themselves consists of index card sized questionnaires with a single response required on each. The response is a mark on a scale with respect to the two items being compared. There are a total of 53 comparisons. Finally, a period is provided for surveyees to offer their insights in response to the surveys and the VAA process. Although not inherent to the survey, this feedback is of paramount importance and will be used in refining the VAA process in the future.

7. POC, this activity, MAJ Robert Clayton, CSCA-FSR, (301)295-0211/5291.

ROBERT KOURY
LTC, IN
Study Director

APPENDIX E

COST DOCUMENTATION

E-1. INTRODUCTION. This appendix provides additional documentation to support the VAA cost analysis process described in Chapter 7. This appendix includes an example of the LCCM template, definitions of the five major cost categories, and an example of the LCCM1 and LCCM2 spreadsheets.

E-2. LCCM TEMPLATE. Figure E-1 provides a complete template of the P-92 cost codes included in the LCCM. The column titled "APPN" shows the appropriation coding corresponding to the P-92 code. Similarly, the column titled "materiel cost category" provides the coding for weapon system cost categories (e.g., flyaway cost) used to calculate the five major weapon system cost categories displayed in Chapter 7, Table 7-5.

PART TWO OF THE LIFE CYCLE COST MODEL - MODIFIED (LCCM-M) FOR NEW OPTIMIZED QUANTITIES AND AVERAGE UNIT COSTS

Msn Area	MIS CODE	Sys.	Categ.	Cost Element	APPN	Total Prev. Years	Current Year	Budget Year	POM Yr 1 1994	POM Yr 2 1995	POM Yr 3 1996	POM Yr 4 1997	POM Yr 5 1998	POM Yr 6 1999	TOTAL POM	TOTAL EPP	Total Outyrs	Total Life Cycle	Materiel Cost Cat.
XXXXXXXX	KSDAML10	4	1.0	Development	R	349.3	111.2	21.2	22.2	23.3	24.4	23.5	0.0	0.0	93.4	0.0	-0.0	575.1	
XXXXXXXX	KSDAML10	4	1.01	Dev Eng, Acq & Modif	RDTE	75.6	41.2	21.2	22.2	23.3	24.4	23.5	0.0	0.0	93.4	0.0	0.0	231.4	
XXXXXXXX	KSDAML10	4	1.011	Engineering	RDTE	5.8	16.8	21.2	22.2	23.3	24.4	23.5	0.0	0.0	93.4	0.0	-0.0	137.2	
XXXXXXXX	KSDAML10	4	1.012	Prod, Eng and Plan	RDTE	22.1	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.3	
XXXXXXXX	KSDAML10	4	1.013	Tooling	RDTE	0.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	2.9	
XXXXXXXX	KSDAML10	4	1.014	Prototype Mfg	RDTE	46.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.9	
XXXXXXXX	KSDAML10	4	1.02	Data	RDTE	6.2	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	14.2	
XXXXXXXX	KSDAML10	4	1.03	System Test and Eval	RDTE	190.9	27.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	218.0	
XXXXXXXX	KSDAML10	4	1.04	System Project Mgt	PA	69.7	31.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.1	
XXXXXXXX	KSDAML10	4	1.05	Training Serv & Equip	RDTE	5.1	0.4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	
XXXXXXXX	KSDAML10	4	1.06	Facilities	RDTE	1.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	3.4	
XXXXXXXX	KSDAML10	4	1.07	Other Dev Costs	RDTE	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	
XXXXXXXX	KSDAML10	4	2.0	Production (Total)	P	0.0	29.0	0.0	240.9	218.5	208.1	202.6	191.5	191.3	1252.9	1233.2	0.0	2515.1	
XXXXXXXX	KSDAML10	4		COM QTY: (primary)					13	13	13	13	13	13	78	78	0	156	
XXXXXXXX	KSDAML10	4		QTY: (secondary)											0.0		0		
XXXXXXXX	KSDAML10	4		AUC Input ($M) - (COM)	$				$18.53	$16.81	$16.01	$15.59	$14.73	$14.72	$16.06	$15.81	$0.00	$15.94	
XXXXXXXX	KSDAML10	4	2.01	Non-Recur	PA	0.0	0.0	0.0	49.5	19.3	3.7	1.0	1.1	1.0	75.6	7.2	0.0	82.9	F
XXXXXXXX	KSDAML10	4	2.011	Initial Prod Facil	PA	0.0		0.0	0.9	1.0	1.9	1.0	1.1	1.0	6.8	7.2	0.0	14.1	
XXXXXXXX	KSDAML10	4	2.012	Prod Base Support*	PA	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
XXXXXXXX	KSDAML10	4	2.013	Depot Mt Prod Equip	PA	0.0		0.0	21.9	4.8	0.0	0.0	0.0	0.0	26.7	0.0	0.0	26.7	
XXXXXXXX	KSDAML10	4	2.014	Other Non-Recur Prod	PA	0.0		0.0	26.7	13.5	1.8	0.0	0.0	0.0	42.0	0.0	0.0	42.0	
XXXXXXXX	KSDAML10	4	2.02	Recur	PA	0.0	0.0	0.0	144.5	148.1	139.5	136.0	138.7	127.:	833.9	850.6	0.0	1684.5	
XXXXXXXX	KSDAML10	4	2.021	Manufacturing	PA	0.0	0.0	0.0	125.6	127.4	129.5	125.9	129.1	115.1	752.7	766.3	0.0	1519.0	
XXXXXXXX	KSDAML10	4	2.0211	Contract	PA	0.0		0.0	89.0	90.5	87.9	84.6	91.6	81.7	525.4	553.6	0.0	1079.0	W
XXXXXXXX	KSDAML10	4	2.0212	Non-Contract	PA	0.0		0.0	26.4	26.0	24.8	23.5	26.5	23.5	150.7	158.3	0.0	308.9	F
XXXXXXXX	KSDAML10	4	2.0213	Warranty	PA	0.0		0.0	4.1	3.6	3.5	3.4	1.0	0.9	16.5	6.1	0.0	22.6	F
XXXXXXXX	KSDAML10	4	2.0214	Other	PA	0.0		0.0	6.1	7.3	13.4	14.5	9.9	9.0	60.1	48.4	0.0	108.5	F
XXXXXXXX	KSDAML10	4	2.022	Recurring Engineering	PA	0.0		0.0	16.4	18.1	7.5	7.7	7.4	6.7	63.8	47.1	0.0	110.9	F
XXXXXXXX	KSDAML10	4	2.023	Tooling	PA	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	F
XXXXXXXX	KSDAML10	4	2.024	Quality Control	PA	0.0		0.0	2.5	2.6	2.5	2.4	2.3	5.3	17.5	37.2	0.0	54.7	F
XXXXXXXX	KSDAML10	4	2.03	Engineering Changes	PA	0.0		0.0	5.0	3.3	2.1	2.0	2.1	1.9	16.3	12.1	0.0	28.5	F
XXXXXXXX	KSDAML10	4	2.04	Data	PA	0.0		0.0	2.9	1.4	0.3	0.3	0.3	0.3	5.5	1.8	0.0	7.3	W
XXXXXXXX	KSDAML10	4	2.05	Sys Test & Eval	PA	0.0		0.0	3.1	11.8	7.4	0.0	0.0	0.0	22.4	0.0	0.0	22.4	F
XXXXXXXX	KSDAML10	4	2.06	Training Serv & Equip	PA	0.0		0.0	18.1	2.4	2.0	1.8	1.7	2.8	28.7	3.6	0.0	32.3	W
XXXXXXXX	KSDAML10	4	2.07	Initial Spares	PA	0.0		0.0	0.0	5.7	14.9	11.6	16.1	16.3	64.5	148.4	0.0	212.9	PR
XXXXXXXX	KSDAML10	4	2.08	Operate/Site Activity	PA	0.0		0.0	0.1	0.2	0.4	0.4	0.4	0.0	1.4	-0.0	0.0	1.4	W
XXXXXXXX	KSDAML10	4	2.09	Other Proc Funded Prod	PA	0.0	29.0	0.0	17.7	26.4	37.7	49.5	31.2	42.1	204.5	209.4	0.0	442.9	
XXXXXXXX	KSDAML10	4	2.091	System Proj. Mgmt	PA	0.0	29.0	0.0	17.4	26.4	28.8	30.2	28.7	25.0	156.4	173.1	0.0	358.5	F
XXXXXXXX	KSDAML10	4	2.092	Peculiar Spt Equip	PA	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	W
XXXXXXXX	KSDAML10	4	2.092	Common Spt Equip	PA	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	LC
XXXXXXXX	KSDAML10	4	2.093	Org Support Equip	PA	0.0		0.0	0.3	0.0	5.3	11.0	1.2	9.5	27.3	20.1	0.0	47.4	LC
XXXXXXXX	KSDAML10	4	2.094	Other Prod. Cost	PA	0.0		0.0	0.0	0.0	3.6	8.3	1.3	7.5	20.7	16.2	0.0	37.0	F
XXXXXXXX	KSDAML10	4	2.10	System Proj. Mgmt	PA	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	F
XXXXXXXX	KSDAML10	4	3.0	Military Construction	MCA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	PA

Figure E-1. LCCM Template
(page 1 of 2 pages)

IIIIIIII	KSDAML10	4	4.0	Fielding (Total)	F	0.0	0.3	1.6	1.5	0.0	5.9	5.1	4.0	3.9	20.5	69.7	0.0	92.0	
IIIIIIII	KSDAML10	4		Fielding (OMA)	FO	0.0	0.2	0.0	0.0	0.0	3.7	2.7	1.4	1.6	9.4	28.9	0.0	38.6	LC
IIIIIIII	KSDAML10	4		Fielding (PA)	FP	0.0	0.1	1.6	1.5	0.0	2.2	2.4	2.6	2.3	11.0	40.8	0.0	53.4	PR
IIIIIIII	KSDAML10	4		QTY: (new input)		0	0	0	0	0	13	13	13	13	52	104	0	156	
IIIIIIII	KSDAML10	4	4.01	System Test & Eval	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	4.02	Training, Serv & Equip	OMA	0.0	0.0	0.0	0.0	0.0	3.2	2.4	0.7	0.6	7.0	13.1	0.0	20.1	
IIIIIIII	KSDAML10	4	4.03	Transportation		0.0	0.3	0.0	0.0	0.0	0.6	0.4	0.7	1.0	2.6	18.8	0.0	21.8	
IIIIIIII	KSDAML10	4	4.031	Transportation (FDT)	PA	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.2	0.3	0.9	6.3	0.0	7.3	
IIIIIIII	KSDAML10	4	4.032	Transportation (SDT)	OMA	0.0	0.2	0.0	0.0	0.0	0.4	0.2	0.5	0.7	1.8	12.6	0.0	14.5	
IIIIIIII	KSDAML10	4	4.04	Initial Repair Parts	PA	0.0	0.0	1.5	1.5	0.0	2.0	2.3	2.3	2.0	10.1	34.5	0.0	46.2	
IIIIIIII	KSDAML10	4	4.05	Sys Spec Base Ops Spt	OMA	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.7	3.2	0.0	4.0	
IIIIIIII	KSDAML10	4	4.06	Other Fund Field	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	4.06	Other Fund Field	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.0	Sustainment (Total)	S	0.0	0.0	0.0	0.0	0.0	8.2	12.8	21.6	30.4	73.2	2316.6	1899.6	4289.4	LC
IIIIIIII	KSDAML10	4	5.0	Sustainment (OMA)	SO	0.0	0.0	0.0	0.0	0.0	7.0	9.2	10.8	10.6	37.7	1011.3	1000.2	2049.2	
IIIIIIII	KSDAML10	4		Sustainment (PA)	SP	0.0	0.0	0.0	0.0	0.0	0.6	2.0	3.7	5.8	12.1	365.3	243.4	620.8	
IIIIIIII	KSDAML10	4		Sustainment (MPA)	SM	0.0	0.0	0.0	0.0	0.0	0.6	1.6	7.2	14.0	23.4	940.0	655.9	1619.3	
IIIIIIII	KSDAML10	4		QTY: (cum: past)		0	0	0	0	0	13	26	39	52	52	156	156	156	
IIIIIIII	KSDAML10	4	5.01	Replenishment		0.0	0.0	0.0	0.0	0.0	0.9	2.6	5.0	7.8	16.3	462.2	241.1	719.6	
IIIIIIII	KSDAML10	4	5.011	Replen Repair Parts		0.0	0.0	0.0	0.0	0.0	0.2	0.7	1.3	2.0	4.2	118.7	61.9	184.8	
IIIIIIII	KSDAML10	4	5.0111	OMA Funded	OMA	0.0	0.0	0.0	0.0	0.0	0.2	0.7	1.3	2.0	4.2	118.7	61.9	184.8	
IIIIIIII	KSDAML10	4	5.0112	Proc Funded	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.012	Replen Spares		0.0	0.0	0.0	0.0	0.0	0.6	2.0	3.7	5.8	12.1	343.5	179.2	531.8	
IIIIIIII	KSDAML10	4	5.013	War Res Repair Pts	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.014	War Reserve Spares	ASF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.015	War Rsrv Repair Parts		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.0151	O&M Funded	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.0152	Proc Funded	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.02	Petrol,Oil,Lubricants	OMA	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.7	1.3	45.3	28.8	75.4	
IIIIIIII	KSDAML10	4	5.03	Ammo/Msl		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.031	Training Ammo/Msl	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.032	War Reserve Ammo/Msl	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.04	Depot Maintenance		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	451.5	433.1	884.5	
IIIIIIII	KSDAML10	4	5.041	Depot Maint Civ Labor	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239.9	230.1	470.0	
IIIIIIII	KSDAML10	4	5.042	Depot Maint. Mat.	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	129.2	123.9	[illegible]	
IIIIIIII	KSDAML10	4	5.043	Materiel (PROC)	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.8	20.9	42.6	
IIIIIIII	KSDAML10	4	5.044	Maint. Support Act.	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.6	58.2	118.8	
IIIIIIII	KSDAML10	4	5.045	Depot Mod. Civ Labor	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.05	Field Maint Civ Labor	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	26.8	50.7	
IIIIIIII	KSDAML10	4	5.05	Field Maint Civ Labor	PA	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.3	3.7	26.8	20.2	50.7	
IIIIIIII	KSDAML10	4	5.06	Transportation	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	11.8	7.1	19.2	
IIIIIIII	KSDAML10	4	5.07	Repl Training		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.8	66.3	43.2	110.2	
IIIIIIII	KSDAML10	4	5.071	Ammo/Msle/Equip	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.072	System Trng Services	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.8	66.3	43.2	110.2	
IIIIIIII	KSDAML10	4	5.073	Contract	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.074	Other	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
IIIIIIII	KSDAML10	4	5.08	MPA	MPA	0.0	0.0	0.0	0.0	0.0	0.6	1.6	7.2	14.0	23.4	940.0	655.9	1619.3	
IIIIIIII	KSDAML10	4	5.09	Sys/Proj Mgmt(Civ)	OMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.8	126.7	207.5	
IIIIIIII	KSDAML10	4	5.10	Modifications/Kits	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.4	43.4	
IIIIIIII	KSDAML10	4	5.11	Other Sustainment		0.0	0.0	0.0	0.0	0.0	6.7	8.2	8.9	7.3	31.1	234.8	293.5	559.5	
IIIIIIII	KSDAML10	4	5.111	Other OMA Funded	OMA	0.0	0.0	0.0	0.0	0.0	6.7	8.2	8.9	7.3	31.1	234.8	293.5	559.5	
IIIIIIII	KSDAML10	4	5.112	Other PA Funded	PA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Figure E-1. LCCM Template
(page 2 of 2 pages)

E-3. **"BIG 5" COST CATEGORIES.** The five major cost categories, commonly referred to as the "Big 5," are described in this paragraph.

a. **Development.** All RDTE costs associated with the development of the materiel system. These include development costs for system armament, training devices, ammunition, missiles, and modifications and integrated logistic support requirements.

b. **Production.** A sum of all procurement appropriation funded costs resulting from the production and introduction of the materiel system into the Army's operational inventory. These include the following:

(1) All costs to the government, defined as contractor costs plus in-house costs necessary to transform the results of development into a fully operational system necessary to initiate operations.

(2) Procurement costs of both those recurring in nature, i.e., costs which occur repeatedly during production and delivery to user organizations and those nonrecurring in nature, i.e., costs which are required to establish a production capability.

(3) All costs resulting from production and introduction into inventory, irrespective of the allocation method. These include unit equipment, maintenance float, and training usage classification.

c. **Military Construction.** Includes both system specific and nonsystem specific requirements. System specific implies the materiel system cannot be fielded without construction. Examples of system specific construction projects are simulator buildings, missile bunkers, and construction of billets associated with fielding new organizations for new systems.

d. **Fielding.** The process of introducing a new materiel system and simultaneously redistributing the replaced materiel system to a unit or a prepositioned site with sufficient resources to achieve the user's given mission objectives. Fielding begins when the ownership of the system is passed from manufacturer to the government, and ends when the materiel system is incorporated into a table(s) of organization and equipment (TOE) or table of distribution and allowances (TDA) unit and operates to permit the unit to accomplish its mission.

e. **Sustainment.** The continuing recurring process of operating and maintaining force structure and materiel systems to perform assigned tests and missions. The level of sustainment is a function of force allocation and training objectives as well as the operating tempo assigned to the individual materiel systems. Sustainment generally begins when the system is fielded and ends when it leaves the Army inventory.

E-4. LCCM1 and LCCM2. Figures E-2 and E-3, respectively, show the LCCM1 and LCCM2 data for production and sustainment costs. The top half of Figure E-2 illustrates the LCCM1 for the quantity shown. The lower half of Figure E-2 (LCCM2) provides the revised production costs that are associated with the revised quantities shown, based on proportional relationships calculated from LCCM1 (see Chapter 7). Similarly, changes in sustainment costs are shown in Figure E-3.

Categ.	Cost Element	APPN	Prev. Years	Current Year	Budget Year	Yr 1 1994	Yr 2 1995	Yr 3 1996	Yr 4 1997	Yr 5 1998	Yr 6 1999	TOTAL POM	TOTAL EPP	Total Outyrs	Total Life Cycle	Materiel Cost Cat.
2.0	Production (Total)	P	35.1	66.9	129.4	130.2	122.1	304.2	132.1	328.4	353.0	1370.0	3338.5	7678.6	12660.6	
	QTY:(primary)			387	824	903	858	2005	785	2139	2308	8998	18196	28909	57014	
	QTY:(secondary)											0	0.0	0		
2.01	Non-Recur	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.011	Initial Prod Facil	PA										0.00	0.0	0.00		
2.012	Prod Base Support*	PA										0.00	0.0	0.00		
2.013	Depot Mt Prod Equip	PA										0.00	0.0	0.00		
2.014	Other Non-Recur Prod	PA										0.00	0.0	0.00		
2.02	Recur	PA	18.77	54.43	106.96	108.46	103.50	269.37	104.61	286.79	309.50	1182.23	2957.5	6656.32	10976.25	
2.021	Manufacturing	PA	18.8	54.4	107.0	108.5	103.5	269.4	104.6	286.8	309.5	1182.23	2957.5	6656.32	10976.25	
2.0211	Contract	PA	18.77	54.43	106.96	108.46	103.50	269.37	104.61	286.79	309.50	1182.23	2957.5	6656.32	10976.25	F
2.0212	Non-Contract	PA										0.00	0.0	0.00		F
2.0213	Warranty	PA										0.00	0.0	0.00		F
2.0214	Other	PA										0.00	0.0	0.00		F
2.022	Recurring Engineering	PA										0.00	0.0	0.00		F
2.023	Tooling	PA										0.00	0.0	0.00		F
2.024	Quality Control	PA										0.00	0.0	0.00		F
2.03	Engineering Changes	PA	0.56	1.63	3.23	3.25	3.11	8.13	3.40	5.63	9.29	35.81	88.5	198.59	328.28	F
2.04	Data	PA	3.19	0.75	0.73	0.55	0.73	2.72	0.69	0.66	0.65	6.39	14.1	23.62	46.82	M
2.05	Sys Test & Eval	PA	8.21		0.95	0.65	0.67	0.69	11.28	0.90	0.93	15.12	35.3	56.04	115.59	F
2.06	Training Serv & Equip	PA	0.08					0.10				0.10	0.3	0.35	0.79	M
2.07	Initial Spares	PA			0.33	0.54	0.61	0.60		2.09	1.65	5.48	17.0	41.21	63.97	PR

Categ.	Cost Element	APPN	Prev. Years	Current Year	Budget Year	Yr 1 1994	Yr 2 1995	Yr 3 1996	Yr 4 1997	Yr 5 1998	Yr 6 1999	TOTAL POM	TOTAL EPP	Total Outyrs	Total Life Cycle	Ma Co
2.0	Production (Total)	P	35.1	66.9	157.1	144.6	129.8	197.7	336.2	328.4	254.8	1391.6	2687.3	7678.6	12017	
	COM QTY: (primary)		0	387	1000	1003	912	1303	1998	2139	1666	9021	14011	28909	53028	
	QTY: (secondary)															
	AUC Input ($M) - (COM)	$	$0.00	$0.17	$0.16	$0.14	$0.14	$0.15	$0.17	$0.15	$0.15	$0.15	$0.19	$0.27	$0.23	
2.01	Non-Recur	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.011	Initial Prod Facil	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
2.012	Prod Base Support*	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
2.013	Depot Mt Prod Equip	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
2.014	Other Non-Recur Prod	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
2.02	Recur	PA	18.77	54.43	129.81	120.47	110.02	175.06	266.24	286.79	223.40	1181.99	2349.0	6656.32	10390.32	
2.021	Manufacturing	PA	18.77	54.43	129.81	120.47	110.02	175.06	266.24	286.79	223.40	1181.99	2349.0	6656.32	10390.32	
2.0211	Contract	PA		54.43	129.81	120.47	110.02	175.06	266.24	286.79	223.40	1181.99	2349.0	6656.32	10371.55	F
2.0212	Non-Contract	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.0213	Warranty	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.0214	Other	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.022	Recurring Engineering	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.023	Tooling	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.024	Quality Control	PA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	F
2.03	Engineering Changes	PA	0.56	1.63	7.92	7.61	3.33	5.23	3.66	3.63	6.70	36.19	70.3	198.59	311.15	F
2.04	Data	PA	3.19	0.75	0.89	0.51	0.77	1.76	1.26	0.85	0.47	6.73	11.2	23.62	45.41	M
2.05	Sys Test & Eval	PA	8.21	0.00	1.15	0.72	0.71	0.45	28.71	0.90	0.67	32.16	28.0	56.04	125.57	F
2.06	Training Serv & Equip	PA	0.08	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.06	0.2	0.35	0.70	M
2.07	Initial Spares	PA		0.00	0.40	0.60	0.65	0.39	0.00	2.09	1.19	4.91	13.5	41.21	59.98	PR

Figure E-2. LCCM1 and LCCM2 (production costs)

Categ.	Cost Element	APPN	Yr 1 1994	Yr 2 1995	Yr 3 1996	Yr 4 1997	Yr 5 1998	Yr 6 1999	TOTAL FDM	TOTAL EFP	Total Outyrs	Total Life Cycle	Materiel Cost Cat.
5.0	Sustainment (Total)	S	34.65	56.83	78.97	80.95	134.07	236.71	622.15	[illegible]	41557.51	47121.71	LC
5.0	Sustainment (OMA)	SO	12.69	21.12	23.53	25.25	44.10	76.65	212.33	1322.1	12102.55	14045.32	
	Sustainment (PA)	SP	7.78	12.77	17.70	13.11	30.73	54.32	141.39	1011.8	9452.77	10605.95	
	Sustainment (MPA)	SM	13.19	22.95	32.70	34.60	59.24	105.75	266.42	2094.1	20127.92	22480.43	
	QTY: (cum: past)		387	1211	2114	3026	4329	6027	6027	20848	52115	52326	
5.01	Replenishment		11.39	19.33	27.65	35.99	49.06	87.37	233.69	1522.4	14679.65	15725.75	
5.011	Replen Repair Parts		4.44	7.54	10.84	11.42	19.38	34.46	88.08	658.2	5831.67	6577.98	
5.0111	OMA Funded	OMA	4.44	7.54	10.84	11.42	19.38	34.46	88.08	658.2	5831.67	6577.98	
5.0112	Proc Funded	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.012	Replen Spares		6.73	10.96	15.50	16.42	27.53	49.11	125.99	894.4	8449.45	9469.89	
5.013	War Res Repair Pts	OMA	0.23	0.35	0.49	0.51	0.79	1.48	3.85	28.4	244.58	276.83	
5.014	War Reserve Spares	ASF	0.34	0.47	0.73	0.64	1.36	2.22	5.76	41.3	353.94	401.05	
5.015	War Rsrv Repair Parts		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.0151	O&M Funded	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.0152	Proc Funded	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.02	Petrol,Oil,Lubricants	OMA	2.05	3.54	5.00	5.26	8.95	15.97	40.77	731.0	2303.12	3074.89	
5.03	Ammo/Msl		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.031	Training Ammo/Msl	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.032	War Reserve Ammo/Msl	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.04	Depot Maintenance		1.96	2.74	2.46	1.81	1.60	2.08	12.66	17.1	125.04	154.47	
5.041	Depot Maint Civ Labor	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.042	Depot Maint. Mat.	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.043	Materiel (PROC)	PA	0.60	0.74	0.51	0.27	0.24	0.31	2.66	2.5	5.77	10.94	
5.044	Maint. Support Act.	OMA	1.37	2.00	1.95	1.54	1.36	1.77	9.99	14.6	117.27	143.53	
5.045	Depot Mod. Civ Labor	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.05	Field Maint Civ Labor	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.05	Field Maint Civ Labor	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.06	Transportation	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.07	Repl Training		2.63	4.37	6.22	6.55	11.12	19.84	50.72	368.4	3379.23	3798.42	
5.071	Ammo/Msle/Equip	PA	0.12	0.12	0.13	0.13	0.24	0.47	1.21	9.1	82.65	93.01	
5.072	System Trng Services	OMA	2.51	4.24	6.09	6.41	10.88	19.33	49.51	359.3	3296.62	3705.41	
5.073	Contract	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.074	Other	OMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.08	MPA	MPA	13.19	22.95	32.70	34.60	59.24	105.75	268.42	2094.1	20127.92	22480.43	
5.09	Sys/Proj Mgmt(Civ)	OMA	0.48	0.49	0.51	0.54	0.47	0.62	3.12	5.0	11.04	19.32	
5.10	Modifications/Kits	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.0	206.76	230.01	
5.11	Other Sustainment		2.62	2.95	3.66	2.57	2.27	2.96	17.01	25.5	198.55	246.87	
5.111	Other OMA Funded	OMA	2.62	2.95	3.66	2.57	2.27	2.96	17.01	25.5	198.55	246.87	
5.112	Other PA Funded	PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	

Figure E-3. LCCM1 and LCCM2 (sustainment costs) (page 1 of 2 pages)

Categ.	Cost Element	APPN	Yr 1 1994	Yr 2 1995	Yr 3 1996	Yr 4 1997	Yr 5 1998	Yr 6 1999	TOTAL POM	TOTAL EPP	Total Outyrs	Total Life Cycle	Materiel Cost Cat.
5.0	Sustainment (Total)	S	34.65	56.83	78.93	79.51	154.14	215.57	619.64	5903.10	45076.95	51622.59	LC
5.0	Sustainment (OMA)	SO	13.69	21.12	28.53	27.74	50.70	69.80	211.58	2187.1	12969.53	15383.61	
	Sustainment (PA)	SP	7.78	12.77	17.70	17.78	35.33	49.47	140.82	1214.5	10256.56	11616.53	
	Sustainment (MPA)	SM	13.19	22.95	32.70	33.98	68.11	96.30	267.23	2501.5	21848.76	24622.45	
	QTY: (cum new input)		387	1211	2114	2972	4977	5762	5762	25024	57314	57314	
5.01	Replenishment		11.39	19.33	27.66	28.47	56.41	79.47	222.73	1947.4	16145.14	18319.44	
5.011	Replen Repair Parts		4.44	7.54	10.84	11.21	22.28	31.39	87.70	790.1	6325.32	7204.76	
5.0111	OMA Funded	OMA	4.44	7.54	10.84	11.21	22.28	31.39	87.70	790.1	6325.32	7204.76	
5.0112	Proc Funded	PA							0.00	0.0	0.00		
5.012	Replen Spares	OMA	6.38	10.96	15.60	16.13	31.66	44.72	125.44	1073.6	9170.67	10372.21	
5.013	War Res Repair Pts	OMA	0.23	0.35	0.49	0.50	0.91	1.35	3.83	34.1	265.19	303.20	
5.014	War Reserve Spares	ASF	0.34	0.47	0.73	0.63	1.56	2.02	5.76	49.6	383.77	439.27	
5.015	War Rsrv Repair Parts		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.0151	OMA Funded	OMA							0.00	0.0	0.00		
5.0152	Proc Funded	PA							0.00	0.0	0.00		
5.02	Petrol.Oil.Lubricants	OMA	2.05	3.54	5.00	5.17	10.29	14.55	40.59	877.4	2449.10	3367.88	
5.03	Ammo/Msl		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	
5.031	Training Ammo/Msl	PA							0.00	0.0	0.00		
5.032	War Reserve Ammo/Msl	PA							0.00	0.0	0.00		
5.04	Depot Maintenance		1.96	2.74	2.46	1.78	1.84	1.90	12.68	20.6	132.98	169.19	
5.041	Depot Maint Civ. Labor	OMA							0.00	0.0	0.00		
5.042	Depot Maint Mat.	OMA							0.00	0.0	0.00		
5.043	Materiel (PROD)	PA	0.60	0.74	0.51	0.26	0.27	0.28	2.67	3.0	6.19	11.98	
5.044	Maint. Support Act.	OMA	1.37	2.00	1.95	1.51	1.56	1.62	10.01	17.6	126.79	157.20	
5.045	Depot Mod Civ Labor	PA							0.00	0.0	0.00		
5.05	Field Maint Civ Labor	OMA							0.00	0.0	0.00		
5.05	Field Maint Civ Labor	PA							0.00	0.0	0.00		
5.06	Transportation	OMA							0.00	0.0	0.00		
5.07	Repl Training		2.63	4.37	6.22	6.43	12.78	18.07	50.49	442.2	3666.76	4160.34	
5.071	Ammo/Msle-Equip	PA	0.12	0.12	0.13	0.13	0.27	0.42	1.20	11.0	89.70	101.87	
5.072	System Trng Services	OMA	2.51	4.24	6.09	6.30	12.51	17.65	49.29	431.2	3577.06	4058.47	
5.073	Contract	OMA							0.00	0.0	0.00		
5.074	Other	OMA							0.00	0.0	0.00		
5.08	MPA	MPA	13.19	22.95	32.70	33.98	68.11	96.30	267.23	2501.5	21848.76	24622.45	
5.09	Sys/Proj Mgmt(Civ)	OMA	0.48	0.49	0.51	0.53	0.55	0.57	3.12	6.0	11.46	21.71	
5.10	Modifications/Kits	PA							0.00	27.7	224.26	251.92	
5.11	Other Sustainment		2.62	2.95	3.66	2.52	2.61	2.69	17.04	30.6	214.62	270.4	
5.111	Other OMA Funded	OMA	2.62	2.95	3.66	2.52	2.61	2.69	17.04	30.5	214.52	270.40	
5.112	Other PA Funded	PA							0.00	0.0	0.00		

Figure E-3. LCCM1 and LCCM2 (sustainment costs) (page 2 of 2 pages)

APPENDIX G

SPONSOR'S COMMENTS

STUDY CRITIQUE

(This document may be modified to add more space for responses to questions.)

1. Are there any editorial comments? NO If so, please list on a separate page and attach to the critique sheet.

2. Identify any key issues planned for analysis that are not adequately addressed in the report. Indicate the scope of the additional analysis needed. none

3. How can the methodology used to conduct the study be improved?

adequate

4. What additional information should be included in the study report to more clearly demonstrate the bases for the study findings? none

5. How can the study findings be better presented to support the needs of both action officers and decisionmakers? adequate

6. How can the written material in the report be improved in terms of clarity of presentation, completeness, and style? adequate

STUDY CRITIQUE (continued)

7. How can figures and tables in the report be made more clear and helpful? no change; adequate

8. In what way does the report satisfy the expectations that were present when the work was directed? Proof was in ~~the~~ its use in the POM build. VAA data and presentation were used in final analysis to assure leadership that the right decisions were made.

In what ways does the report fail to satisfy the expectations?

None

9. How will the findings in this report be helpful to the organization which directed that the work be done? Lays solid foundation for further work; more inclusive list of modernization systems and their value added. Helps in formulating essential ~~[illegible]~~ elements of analysis ~~and [illegible] frames~~ for program development and balance analysis.

If they will not be helpful, please explain why not.

N/A

10. Judged overall, how do you rate the study? (circle one)

Poor Fair Average Good Excellent

- Simply outstanding work.
- a [illegible] foundation for even better [illegible] to come.

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF FOR OPERATIONS AND PLANS
WASHINGTON, DC 20310-0400

REPLY TO
ATTENTION OF

DAMO-FDZ 12 August 1992

MEMORANDUM FOR DIRECTOR, US ARMY CONCEPTS ANALYSIS AGENCY

SUBJECT: Army Program Value Added Analysis 94-99 (VAA 94-99) Study Report CAA-SR-92-10

1. Reference Draft study, dated June 1992, SAB.

2. The draft study report has been evaluated and accurately documents the VAA methodology and work performed to support the Long Range Research Development and Acquisition Plan and the POM for FY 1994-1999. The methodology and its application provided significant insight to tradeoffs in acquisition of major modernization systems and their war fighting value. In summary, the development of the methodology was well formulated and thorough, the determination of the "values" for selected systems was sound, and the presentation of results was timely, clear and succinct. The study, its director and supporting analysts, provided an exceptional contribution to decision makers leading to a balanced FY 1994-99 POM.

3. A study critique is attached. No additions or deletions to the distribution list are suggested.

for Carothers, COL FD/Deputy

Encl

JAY M. GARNER
Major General, GS
Assistant Deputy Chief of Staff
for Operations and Plans,
Force Development

STUDY CRITIQUE

(This document may be modified to add more space for responses to questions.)

1. Are there any editorial comments? No. If so, please list on a separate page and attach to the critique sheet.

2. Identify any key issues planned for analysis that are not adequately addressed in the report. Indicate the scope of the additional analysis needed. All key issues addressed

3. How can the methodology used to conduct the study be improved?

As discussed in report.

4. What additional information should be included in the study report to more clearly demonstrate the bases for the study findings?

No additional information needed.

5. How can the study findings be better presented to support the needs of both action officers and decisionmakers?

Presentation fully supports need of both.

6. How can the written material in the report be improved in terms of clarity of presentation, completeness, and style?

No improvement suggested.

STUDY CRITIQUE (continued)

7. How can figures and tables in the report be made more clear and helpful?

Figures and tables need no improvement

8. In what way does the report satisfy the expectations that were present when the work was directed?

Expectations are fully met with documentation of the value added methodology

In what ways does the report fail to satisfy the expectations?

none

9. How will the findings in this report be helpful to the organization which directed that the work be done?

This methodology along with applications helped validate program decisions in the FY 94-99 POM

If they will not be helpful, please explain why not.

10. Judged overall, how do you rate the study? (circle one)

Poor Fair Average Good Excellent

APPENDIX H

DISTRIBUTION

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GLOSSARY

ABBREVIATIONS, ACRONYMS, AND SHORT TERMS

155 ER	155mm extended range round
155 LtWt	155mm lightweight howitzer
155 TGP	155mm terminally guided projectile
AAWS-M	Advanced Antitank Weapons System - Medium
AC	Active Component
ACP	Army cost position
ACR	armored cavalry regiment
ADATS	Air Defense Antitank System
ADCSOPS	Assistant Deputy Chief of Staff for Operations and Plans
AFAS	Advanced Field Artillery System
AFP	Analysis of Force Potential
AGS	Armored Gun System
AHP	analytical hierarchy process
AMC	US Army Materiel Command
AMS-H	Advanced Missile System - Heavy
ARIM	Army Resource Integration and Management (study)
ARSTAF	Army Staff
ARV	armored recovery vehicle
ASA(RDA)	Assistant Secretary of the Army (Research, Development, and Acquisition
ASF	Army stock fund
ASIOE	associated support item(s) of equipment
ASM	armored systems modernization
AT	antitank
ATACMS	Army Tactical Missile System

ATAS	air-to-air STINGER
ATGM	antitank guided missile
AVLB	armored vehicle launched bridge
Adv SEMA	advanced special electronic mission aircraft
BAT	brilliant antiarmor technology
BCE	baseline cost estimate
BFS	Blue force surviving
BLK	block
BOIP	basis of issue plan
C2	command and control
C4I	command, control, communications, computers, and intelligence
CAA	US Army Concepts Analysis Agency
CEAC	US Army Cost and Economic Analysis Center
CFE	Conventional Forces Europe
CFV	cavalry fighting vehicle
CI	consistency index
CIS	Confederation of Independent (former Soviet) States
CITV	Commander's Independent Thermal Viewer
CMV	combat mobility vehicle
COFM	correlation of forces and means
CORBAN	Corps Battle Analyzer (model)
CR	consistency ratio
CSA	Chief of Staff of the Army
CS	combat support
CSS	combat service support
DAB	Defense Acquisition Board
DAS	Director of the Army Staff

DCSINT	Deputy Chief of Staff for Intelligence
DCSLOG	Deputy Chief of Staff for Logistics
DCSOPS	Deputy Chief of Staff for Operations and Plans
DCSPER	Deputy Chief of Staff for Personnel
DCSRM	Deputy Chief of Staff for Resource Management
DMZ	demilitarized zone
DOD	Department of Defense
DPAE	Director, Program Analysis and Evaluation
DPICM	dual-purpose improved conventional munition
DUSA(OR)	Deputy Under Secretary of the Army for Operations Research
EEA	essential element(s) of analysis
EPP	Extended Planning Period
FA	field artillery
FAAD C21	forward area air defense system command, control, and intelligence
FAASV	field artillery ammunition support vehicle
FARP	forward arming and refueling point
FARV-A	future armored resupply vehicle - artillery
FAS	Force Accounting System
FDT	first destination transportation
FER	force exchange ratio
FIFV	future infantry fighting vehicle
FMTV 2.5/5	family of medium tactical vehicles 2.5-ton/5-ton
FUC	first unit cost
FY	fiscal year
GBCS-L/H	ground based common sensor - light/heavy
GBS	ground based sensor

GS	general support
GSR	general support role
HAB	heavy assault bridge
HET	heavy equipment transporter
HMMWV	high mobility, multipurpose wheeled vehicle
HQDA	Headquarters, Department of the Army
IFV	infantry fighting vehicle
IGB	inter-German border
IMO	information management office
IMSL	international mathematical and statistical library
ITV	Improved TOW vehicle
JSTARS	Joint Surveillance Target Attack Radar System
LCCM	Life Cycle Cost Model
LER	loss exchange ratio
LIN	line item number
LOSAT	line of sight antitank
LP	linear programming
LRRDAP	Long-Range Research, Development, and Acquisition Plan
M	millions
MACOM	major Army command
MADM	multiple attribute decisionmaking
MCA	Military Construction, Army
MDEP	management decision package
MIP	mixed integer program
MISM	major item system map
MLRS SADARM	multiple launch rocket system sense and destroy armor
MLRS TGW	multiple launch rocket system terminally guided weapon

MNS	mission needs statement
MOE	measure(s) of effectiveness
MPA	Military Procurement, Army
MPR	maximum production rate
MRC-E	Major Regional Contingency - East
MRC-W	Major Regional Contingency - West
MRL	multiple rocket launcher
MSR	minimum sustaining rate
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, and chemical
NEA	Northeast Asia
NLOS	nonline of sight
NLOS-AT	nonline of sight - antitank
NLOS-CA	nonline of sight - combined arms
O&S	operating and support
OBV	obstacle breach vehicle
ODCSOPS	Office of the Deputy Chief of Staff for Operations and Plans
OMA	Operation and Maintenance, Army
OPA	Other Procurement, Army
OPTEMPO	operational tempo
ORSA	operations research systems analysis
OSD	Office of the Secretary of Defense
OSE	organization support equipment
OSL	Optimization Software Library
PA	Procurement, Army
PAED	Program Analysis and Evaluation Directorate
PC	personal computer

PE	program element
PEO	Program Executive Office
PLS	palletized loading system
PM	Program Manager
POM	Program Objective Memorandum
PPBES	Planning, Programming, Budgeting, and Execution System
PROBE	Program Optimization and Budget Evaluation
Pk	probability of kill
QRA	quick reaction analysis
qty	quantity
RAM	reliability, availability, and maintainability
RDA	research, development, and acquisition
RDAISA	Research, Development, and Acquisition Information System Agency
RDTE	research, development, test, and evaluation
RFM	Red force movement
ROC	required operational capability
ROF	rate of fire
RSM	response surface methodology
SADARM	sense and destroy armor
SARDA	Secretary of the Army for Research, Development, and Acquisition
SDT	second destination transportation
SELCOM	Select Committee
SHORAD	short-range air defense
SIAM	secondary impact analysis modifier(s)
SIMA	Systems Integration and Management Activity
SME	subject matter expert

SSN	standard study number
SSPK	single shot probability of kill
SWA	Southwest Asia
TAA	Total Army Analysis (study)
TACJAM	tactical jamming
TAEDP	total Army equipment distribution program
TAFCS	The Army Force Cost System
TDA	table(s) of distribution and allowances
TGP	terminally guided projectile
TGW	terminally guided weapon
TOA	total obligational authority
TOE	table(s) of organization and equipment
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution (model)
TOW	tube-launched, optically tracked, wire-guided
TOW 2B	tube-launched, optically tracked, wire-guided missile 2B
TRADOC	US Army Training and Doctrine Command
USMA	US Army Military Academy
VAA	Value Added Analysis
VAAC	Value Added Analysis Capability
VALOR	Value Added Linear Optimization of Resources (model)
VEMASID	vehicle magnetic signal duplicator
VIC	Vector-In-Commander (model)
WAM	wide area mine
WTCV	wheeled and tracked vehicles

CAA (Concepts Analysis Agency, United States Army)	**ARMY PROGRAM VALUE ADDED ANALYSIS 94-99 (VAA 94-99)**	**STUDY SUMMARY CAA-SR-92-10**

THE REASON FOR PERFORMING THE STUDY was to provide the Director for Program Analysis and Evaluation, and the Deputy Chief of Staff for Operations and Plans (DCSOPS) an analytical methodology and capability to support the development of a balanced and effective Army Program.

THE STUDY SPONSORS are the Director for Program Analysis and Evaluation (DPAE), Office of the Chief of Staff, Army, and the Technical Advisor, Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS), Headquarters, Department of the Army (HQDA).

THE STUDY OBJECTIVES were to:

(1) Produce VAA coefficients and feasible acquisition alternatives for major item systems proposed by Headquarters, Department of the Army (HQDA) Long-Range Research, Development, and Acquisition Plan (LRRDAP) and constrained by modernization total obligational authority (TOA). The process must measure and analyze the capability of US Army forces to conduct conventional operations in scenarios consistent with the Illustrative Planning Scenarios of the Defense Planning Guidance, Fiscal Year (FY) 1994-1999.

(2) Identify and develop a Value Added Analysis Capability (VAAC) to include all appropriate hardware, software, and interfaces. The VAAC must tap major authoritative Army data bases such as the Total Army Equipment Distribution Program (TAEDP), Force Accounting System (FAS), and the Army Force Cost System (TAFCS).

(3) Identify or develop models and techniques that support the VAA methodology. The VAAC and related models must be capable of operating in a "quick turnaround" environment, defined as 1 week or less.

(4) Conduct a demonstration of the refined methodology and VAAC prior to the building of the 1994-1999 Program Objective Memorandum (POM).

(5) Continue the refinement and implementation of the VAA methodology for estimating the value of either competing major item systems or management decision packages (MDEPs) to the Total Army Program.

THE SCOPE OF THE STUDY included the research, development, and acquisition (RDA) appropriation for selected major item systems in FY 1994 and FY 2008.

THE MAIN ASSUMPTION of this study is that HQDA needs a relatively quick method for conducting program tradeoffs which has sound analytical underpinnings.

THE BASIC APPROACH of this study was to:

(1) Enhance and expand the analytic approach for program issue tradeoffs developed in Phase I of the VAA study effort.

(2) Develop a VAAC for implementing the methodology to include software modules where appropriate.

(3) Demonstrate the VAAC using issues from the 94-99 POM issue cycle.

THE PRINCIPAL FINDINGS of the study were:

(1) The Value Added Analysis study framework, as developed in the VAA Phase I Study, was shown to be useful in evaluating POM issues.

(2) The use of an experimental design and a response surface methodology was found to be an effective means to determine system contribution to combat results.

(3) The Life Cycle Cost Model (LCCM) is a useful tool for providing action officers with detailed cost estimates for candidate POM programs.

(4) The development of a mixed integer programming formulation that allowed consideration of cost/quantity relationships and handles fixed production costs and research, development, test, and evaluation costs explicitly was shown to be an extremely effective method of cost-benefit analysis.

(5) Additional research is required to find an improved method of effectiveness integration to replace the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Model.

THE STUDY EFFORT was directed by LTC Robert R. Koury, Force Systems Directorate, US Army Concepts Analysis Agency (CAA).

COMMENTS AND QUESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FSR, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

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